Book of abstracts

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This booklet contains all abstracts accepted for Themes 1 – 8, as of 16th May 2025.

It is ordered by session, and includes the type of presentation that is allocated

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk [Invited]

Optimization of lithium diffusion modelling in plagioclase: implications for pre-eruptive timescales assessment

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Lithium diffusion modelling in plagioclase is used to retrieve timescales, varying from seconds to hours, of fast pre-eruptive processes, such as decompression-induced degassing. Effects related to diffusion anisotropy and random orientation of the exposed crystal surface can impact models results yielding to underestimation of Li diffusion timescales. In order to evaluate these effects, we applied Li diffusion modelling to core-to-rim profiles acquired by LA-ICP-MS on different sections of 8 plagioclase crystals from Stromboli volcano (Italy). The crystal sections include the (010) basal section intersecting the core of the crystals and multiple (3 to 4) parallel sections oriented perpendicular to (010), subsequently exposed at distance steps of ~65–270 µm starting from the section intersecting the core of each crystal. The model accounts for Li analytical uncertainty and, through bootstrapping, finds a best-fit timescale in a set of 1000 time values. Longer best-fit timescales were obtained in section perpendicular to (010) intersecting the core of each crystal. Depending on diffusion coefficient (*D*), best-fit timescales range from 129 to 1134 sec ($D1 = 4.5e^{-11}$ m^2 s^{-1}) and from 803 to 7405 sec ($D2 = 6.7e^{-12}$ m^2 s^{-1}). Timescales determined in other crystal sections are 58–94% shorter, meaning that large underestimates can derive from random crystal surfaces. By comparing these estimates with Li diffusion timescales obtained from previous studies at Stromboli, we discuss the influence of the proper crystal section, *D* and error propagation. The presented methodology allows for a more robust assessment of Li diffusion timescales in plagioclase and is applicable to other volcanoes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

Harnessing X-ray microtomography and 3D diffusion models to constrain magmatic timescales in complex crystals

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Magmatic minerals act as natural archives of the timescales of volcanic processes (e.g., fractional crystallization, mixing, degassing, and decompression rates). Part of the knowledge on the timescales of volcanic processes is retrieved from modeling diffusion gradients observed in minerals and melt. Most diffusion modeling studies use a one-dimensional model that does not account for diffusion from multiple directions or sectioning effects. In some rare cases, considerations of 3D diffusion were explored using ideal crystal shapes, but textural crystal complexities have yet to be properly accounted for. X-ray micro-tomography (X-μCT) scans offer the possibility to access the full morphological representation of the crystal and melt inclusions. We used this technique to create the first-ever real 3D diffusion model of natural olivine with its melt inclusions. Olivine grains are from the 1820 Keanakākoʻi golden pumice eruption at Kīlauea (Hawaiʻi) and display a wide range of textures (polyhedral to skeletal). By employing a sophisticated finite element 3D multiphase diffusion model, we modeled Fe-Mg and H diffusion in olivine and its melt inclusions to estimate mixing timescales, ascent-related cooling rates, and decompression rates. This innovative approach combining X-μCT and diffusion modeling can fully integrate crystal morphology and melt inclusion morphology to access more accurate diffusion timescales and decompression rates, without worrying about the location of the diffusion profile in a section. This technique not only promises to refine our understanding of diffusion timescales and decompression rates in volcanic systems but also opens new avenues for investigating other critical mineral phases in diffusion chronometry.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

Exploration of melt inclusion geometry, entrapment and post-entrapment processes in 3D using X-Ray and diffraction computed tomography

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Understanding the origins and fidelity of geochemical signatures recorded in melt inclusions (MI) - and associated vapour bubbles - is essential for accurate reconstructions of magmatic plumbing systems. However, inaccuracies in 2D-to-3D conversion methods lead to over- and underestimation of glass inclusion and bubble volumes. These volumetric uncertainties propagate into reconstructions of MI volatile contents and inclusion-to–bubble volume ratios, and MIs may be incorrectly inferred to cross the defined boundary for heterogeneous entrapment. Further, entrapment and post-entrapment processes aren't always evident in 2D images, resolvable using optical microscopes, or preserved during destructive sample preparation. Acquiring 3D MI and bubble volumes offers an enticing prospect towards accurate interpretation of geochemical data and preservation of key textural indicators of crystallization and post-entrapment processes. We present 3D olivine-MI-vapour bubble morphologies and their geometric and structural relationships for primitive olivine crystals from three case study eruptions from Iceland (Stapafell and Borgarhraun) and the Canary Islands (El Hierro), acquired via X-ray diffraction and computed tomography. Our 3D data reveal several MI morphologies present across olivine hosts representative of a range of growth mechanisms. Reconstructions of complex vapour bubble-MI geometries linked to microscopic fractures provide evidence of post-entrapment processes not visible via optical microscopy. Our findings demonstrate the importance of exploring MI-host morphologies and relationships in 3D to gain insights into crystallisation, MI entrapment and post-entrapment processes and ensure reliable interpretation of geochemical datasets.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

Bubbly melt trapped in Youngest Toba Tuff quartz reveals pre-eruptive magma vesicularity, compressibility, and why the eruption was so big

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The 75 ka eruption of the Youngest Toba Tuff is one of few eruptions documented to be initiated by volatile accumulation, an eruption initiation mechanism much less common than recharge or rejuvenation. We searched for evidence of pre-eruptive exsolved volatiles in the erupted products of the Youngest Toba Tuff by using x-ray microtomography to image six quartz crystals. The imaged quartz crystals contain populous bubbly melt inclusions. Analysis of 59 melt inclusions show an average of 8.6 bubble vol.% and 2.2 bubbles (maximum 11 bubbles) per inclusion. We found that 51% of inclusions have a bubble vol.% greater than 7, the maximum vol.% that could be caused by post-eruptive hydrogen diffusion and host-inclusion thermal volume changes, showing that these bubbly inclusions sampled an at-depth exsolved vapor phase that was co-entrapped with the melt during pre-eruptive crystal growth. Many (56%) of these bubbles are also attached to small oxide crystals, recording evidence of heterogeneous bubble nucleation in the magma reservoir. These physical observations support the chemical analyses that suggest the eruption of the Youngest Toba Tuff was initiated by volatile accumulation, a seldom identified eruption initiation mechanism in large silicic systems. Using our vesicularity measurements and Voigt-Reuss-Hill elastic moduli bounds, we hypothesize that this exsolved vapor phase can increase magma compressibility by up to an order of magnitude. These large changes in magma compressibility can suppress eruption initiation, promoting magma accumulation in the crust, and lead to especially large eruptions such as that responsible for the Youngest Toba Tuff.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

Unlocking the H2O archive in plagioclase: experimental plagioclase – dacite melt H2O partitioning at crustal conditions

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H_2O has a fundamental impact on volcanic petrology and hazards, particularly in arc volcanoes. The proximity of many arc volcanoes to population centers (e.g., Pinatubo, Mount St. Helens) thus highlights the need for reliable proxies on pre-eruptive H_2O concentrations. Our goal is to establish a robust hygrometric proxy for dacitic magmas by experimentally determining the partitioning of H_2O between plagioclase and dacite melt, which has so far been unreported. Plagioclase is well suited for this purpose due to its ubiquity in arc magmas, extended thermal stability, and lower H diffusivity relative to other silicate phases[1]. We measured H_2O concentrations of plagioclase and coexisting dacitic glass by SIMS in vapor-saturated experiments conducted on a Mount St. Helens dacitic composition. Experiments were performed in piston-cylinder devices[2,3] at 900-1000 ºC, 400-1310 MPa, and fO_2 conditions near the Re-ReO_2 buffer. Preliminary results from six experiments (An_{43-60}) show 3.7-5.6 wt.% $H_2O^T_{glass}$ and 94-137 µg/g H_2O_{plag}, resulting $D^{plag-glass}_{H2O}$ in between $2\text{-}3 \times 10^{-3}$. Key trends include the positive correlation between H_2O_{plag} and pressure, and a negative An#-$D^{plag-glass}_{H2O}$ correlation. These findings pave the way for reconstructing long-term variations in pre-eruptive H_2O concentrations by analyzing H_2O contents in plagioclase in volcanic deposits, partially overcoming shortcomings of other proxies, such as melt inclusions, H contents in faster diffusing phases or plagioclase-melt hygrometry.

[1]Johnson & Rossman (2013), Am Mineral, 98, 1779-1787 [2]Blatter, Sisson & Hankins (2017), Contrib Mineral Petrol, 172, 27 [2]Blatter, Sisson & Hankins (2023), Contrib Mineral Petrol, 178, 33

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

Missing atmospheric sulfur in the 15 January 2022 Hunga eruption and implications for completeness of paleoclimate-volcanic records

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The explosive January 2022 Hunga eruption in Tonga injected unprecedented volumes of water into the upper atmosphere and generated widespread climatic impacts. However, it ejected anomalously little sulfur. We explain the missing sulfur with volatile budgets calculated from a unique set of timed volcanic ash samples through the eruption. We show that magma was stored in a weakly stratified reservoir at 2.1 to >5.6 km-depth. Magma rose from its initial sites in <2 minutes then fragmented and quenched at 400–1000 m below sea-level. Ash grains preserve micro-scale chemical mingling and show contrasts in content of fast-diffusing magmatic water. The 11-hr eruption released a total of 319 Tg of magmatic water, which is <10% of the amount convected into the plume by magmatic-volatilization of sea-water. Of the total 9.4 Tg sulfur output we show that >93% of it directly entered sea-water during eruption and fragmentation. Our results raise the concern that satellite SO_2 monitoring may underestimate the magma output of eruptions driven by submarine explosivity. The low mass of sulfur erupted to the atmosphere likely renders submarine explosive eruptions nearly invisible in ice-core records, even though Hunga has had an obvious climate influence, which resulted from dispersion of other volcanic compounds. Volcano-climate risk may be higher than current estimates.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

Unlocking Volatile Budgets and Saturation States in Eruptions of Varying Magnitude: Insights from Apatite at Santorini, Greece

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Volatiles play a crucial role in magmatic systems and in conditioning them for remobilisation and eruption. Understanding changes in volatile concentrations and saturation state of a magma is essential for establishing the conditions necessary for explosive eruptions of varying magnitudes and probing the dynamics of complex mushy systems. Santorini (Greece) is an ideal location to investigate the changes in a magmatic system between Plinian and smaller inter-Plinian eruptions. Previous studies indicate most magmas at Santorini are volatile saturated, and modelling demonstrates that eruption dynamics are sensitive to the presence of exsolved gas. Here, we present new volatile data from apatite (H_2O, Cl, F) for several Plinian and inter-Plinian eruptions from Santorini. Apatite provides a robust tool for tracking changes in volatile concentrations and the saturation state of magma. We utilise identified apatite volatile trends alongside an iterative forward model to estimate the initial volatile concentrations of the melt and the saturation conditions under which the magmas likely fractionated. Our data suggests that while magmas from some of the major Plinian eruptions were likely volatile saturated, this is not consistent. Apatite from inter-Plinian and intermediate composition eruptions seem to record volatile undersaturated conditions and were stored and fractionated at greater depths prior to eruption. Our modelling results of volatile concentrations align well with melt inclusion data, and the estimated required degree of crystallisation is consistent with phase equilibria studies. We further refine the halogen volumes released during large Plinian eruptions and present an updated model for the plumbing system at Santorini.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

Pressure-temperature-volatile contents variability of magmas feeding caldera-forming eruptions at Toba volcano

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Toba volcano in Sumatra, Indonesia is known for four large caldera-forming eruptions in Quaternary, including the famous Youngest Toba Tuff (YTT) at ~74 ka and three older eruptions, namely HDT (~1.42 Ma), OTT (~784 ka), and MTT (~504 ka) that were less studied. Here we apply conventional and machine-learning based geothermobarometers and hygrometers to the four Toba tuffs, to determine the P-T conditions and volatile budgets of the sub-caldera magma. We found that the dacitic magma of the HDT had distinctly higher storage and pre-eruptive P-Ts, as well as lower H_2O contents than the rhyolitic magmas of the later eruptions. Specifically, estimates for magma storage P-Ts from biotite-amphibole are similar for the OTT, MTT and YTT (T=770–825 °C; P=200–320 MPa and 100–200 MPa from biotite and amphibole respectively). Estimates of P-Ts from matrix glasses show two distinct populations for the HDT (median: 783 °C and 200 MPa, and 867 °C and 330 MPa) but single populations of lower values for the OTT, MTT and YTT (median: 750 ±20 °C and 120 ±30 MPa). Estimates for melt H_2O contents from apatite show generally lower values for the HDT (mostly 3–5 wt%, indicating saturation P<140 MPa) than the OTT-MTT (mostly >5 wt%) and YTT (mostly >9 wt%, indicating saturation P>320 MPa). These indicate that the magma reached volatile saturation at different conditions before different eruptions, and the role that volatile saturation plays in eruption triggering may vary between caldera cycles.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

The origin of high-Ni olivines in Mexican arc magmas revisited with new temperature constraints from olivine-spinel aluminum exchange thermometry

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High-Ni olivines have higher Ni concentrations than expected for olivines crystallizing in partial peridotite melts. Their discovery in intraplate and arc magmas has caused much controversy concerning their implications for magma genesis. While some studies link high-Ni olivines to Ni-rich melts from secondary mantle pyroxenites, others argue that compositional and thermal variations of peridotite melt sufficiently increase the composition- and temperature-sensitive olivine/melt partition coefficient for crystallizing high-Ni olivine. Here we re-evaluate the origin of high-Ni olivines from the Trans-Mexican Volcanic Belt (TMVB) using olivine crystallization temperatures from olivine-spinel aluminum exchange thermometry. The TMVB olivines crystallize at comparatively low temperatures of ~1147±25°C in hydrous, silicic, and less magnesian (≤10 wt% MgO) primary arc magmas. Despite a moderate melt Ni ≤220 ppm, the increases sufficiently to crystallize olivines with up to ~3500 to 4000 ppm Ni, which accounts for ~90% of TMVB high-Ni olivines. However, an increased melt Ni still best explains a small population of olivines with very high Ni concentrations of >4000 to 5500 ppm. Crystal-scale data suggest that these Ni-rich melts form by reactive melt/wall rock interaction in peridotite-hosted mantle conduits continuously fluxed by silicic slab melts. Thus, the very high-Ni olivines provide a rare view of the deep mantle plumbing system beneath volcanic arcs, whereby it remains open whether the conditions of their formation only rarely exist, or whether they are only seldom preserved en route to the surface through the overlying crust.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Talk

Can halogen contents of olivine-hosted melt inclusions track time-dependent sampling of mantle heterogeneities during single eruptions?

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Volatile heterogeneity in the Earth's mantle has been created by volatile input and output over time. Basaltic eruptions at oceanic islands can sample these mantle heterogeneities and capture their diverse geochemical signatures in crystal-hosted melt inclusions. However, the extent to which melting and mobilisation of mantle heterogeneities influence magma volatile budgets during a single eruption remains poorly understood, because the time-dependencies of those processes are not well constrained by measurements. To address this, we plan to measure Cl, Br and I in melt inclusions from Iceland and the Canary Islands. Halogens are sensitive tracers of recycled material, making them ideal for tracking time-dependent sampling of different mantle reservoirs. We will use neutron-irradiated noble gas mass spectrometry to measure halogens, following two different approaches: bulk analyses of single olivine grains containing melt inclusions, and *in situ* analyses of individual melt inclusions. Our first objective is to constrain the halogen signatures of three mantle types by analyzing melt inclusions from three compositionally distinct localities: Borgarhraun (depleted) and Stapafell (enriched) (Iceland), and El Hierro (recycled) (Canary Islands). Secondly, we will use the obtained halogen signatures to construct high-resolution time series of halogen content in melts and their mantle sources for two recent eruptions showing time-dependent geochemical variability: 2021–2022 Fagradalsfjall and 2021 Cumbre Vieja (La Palma, Canary Islands). Finally, by linking temporal variations in magma halogen content with *in situ* gas flux measurements and observed changes in eruptive style, we aim to evaluate whether time-dependent differential sampling of heterogeneous mantle reservoirs influences eruption dynamics.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Contribution of melt inclusions to the origin and evolution of the primitive magmas of Mount Cameroon volcano

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The Mont Cameroun volcano is fed by magmas that originate at depth from the partial melting of the lithospheric (or asthenospheric) mantle. Before reaching the Earth's surface, magmas are transferred through a network of reservoirs. The analysis of the melt inclusions from Mount Cameroon has enabled to characterize primitive liquids in relation to the lavas. Melt inclusions are found in microdroplets trapped in the early minerals (olivines) from the pyroclastic products. The study of the major elements of magmatic inclusions, trapped in the most magnesian olivines (Mg#84-86) of Mount Cameroon revealed "primitive" basanite and alkaline basalt liquids of variable composition compared to the lavas. The study of these liquids revealed basanite and alkaline basalts of variable composition compared with the much more uniform basalts of the Mount Cameroon magmatic series. The geochemistry of these trapped liquids shows that: - the original primitive lavas did not undergo the evolutionary process by FC, but rather fundamentally (or exclusively) underwent the process of partial melting; - variations in the trace element content of primitive liquids directly reflect a variation in the rate of partial melting of a homogeneous mantle source. The spectra of fluid inclusions show HIMU characteristics. The significance of HIMU signatures is more likely to be associated with mantle plumes geochemical signatures which provides evidence for deep mantle source for these geochemical domains. The "primitive" liquids and lavas of Mount Cameroon represent a co-genetic sequence formed by varying degrees of partial melting of their source. Geochemical signatures such as the very high La/Yb ratios of the Mount Cameroon melt inclusions (>20) characterize a garnet lherzolite source. **Keywords**: Primitive magma, Partial melting, Fractional crystallization, Alkali basalt, Mount Cameroon active volcano.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Crystal fragmentation inducing euhedral crystal habits in volcanic rocks: the fracture history of crystals from various tectonomagmatic settings

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Fracturing of crystals in volcanic rocks is a phenomenon that has been widely recognized. However, the history of repeated crystal fragmentation as recorded by the phenocrysts carried in volcanic rocks is yet to be considered. We provide examples from hot spot, arc, back-arc and ocean ridge settings indicating that crystals often display linear fractures, some following cleavage planes, and show that elemental mapping is useful to identify such fractures. We provide evidence of cryptic zoning and fracture annealing. Crystal fragmentation appears to be a fundamental and recurrent process operating in magmatic systems, impacting both internal crystal zoning patterns as well as their final crystal habit in erupted rock samples. Euhedral crystal habits can be the result of edge fracturing along cleavage planes, rather than unhindered crystal growth within a melt phase. How common such edge fractures are in generating euhedral crystals will require a larger dataset and statistical evaluations that are beyond the scope of this pilot study. Such studies will be required to evaluate if crystal fracturing impacts the application of chronological methods, including geospeedometric and crystal size distribution studies directed at volcanic hazard mitigation. Either way, the use of advanced imaging techniques to decipher pre-eruptive processes remains paramount.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Insights into the Magmatic Plumbing System of Pavlof Volcano, Alaska through Volatiles in Olivine-Hosted Melt Inclusions

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Pavlof Volcano, Alaska, USA, is a frequently active, basaltic-andesite stratovolcano that typically erupts with limited or no recognized precursory signals. Previous studies have found little evidence to support the presence of a persistent shallow magma reservoir, but barometry studies have been limited. Here we investigate Pavlof Volcano's magma system using volatile concentrations in olivine-hosted melt inclusions from two prehistoric eruptions. Results from Fourier-transform infrared spectroscopy and electron microprobe analyses find that inclusions contain <0.5 to >5 wt% H_2O (N=61), 400–2,800 ppm S (N=14), <30 ppm (~detection limit) to 700 ppm CO_2 (N=61), and Fo=70–75 in the host olivine. CO_2 in shrinkage bubbles of inclusions is accounted for with thermodynamic modeling in MIMiC. Analyses of sulfur Kα peak shifts suggest the system fO_2 is ~NNO+0.5. H_2O and CO_2 volatile saturation pressures calculated with the MagmaSat model indicate equilibrium pressures ranging from <100 bar (<0.5 km) to 2500 bar (9 km). Degassing models show that no single degassing path from one initial volatile concentration can explain all the data. A possible explanation for the wide range of H_2O concentrations and saturation pressures is that some magma stalled at a depth of several kilometers and experienced diffusive H_2O-loss. Furthermore, while most CO_2-rich melt inclusions follow closed-system degassing paths, a second population of inclusions with low CO_2 is more consistent with open-system degassing paths and shallow entrapment, potentially indicating variability in degassing processes. This study aims to provide new constraints on Pavlof's magma plumbing system to help inform future volcano monitoring efforts.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Deciphering Fe- and S-XANES in melt inclusions with silicate-carbonate immiscibility: a case study from Hanang volcano (Tanzania)

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For the first time, the K-edge X-ray absorption near edge structure (µXANES) method has been used on melt inclusions composed of both silicate glass and carbonate phase. This study describes microscale iron (Fe) and Sulfur (S) µXANES measurements on nepheline-hosted melt inclusions preserved in Hanang lavas. Hanang is a volcano in the southern part of the east branch of the East African Rift (North Tanzania Divergence) and represents volcanism at the early stage of continental break-up; characterized by CO_2-alkaline-rich magmas and silicate-carbonate immiscibility process at crustal level. Silicate glasses from Hanang display relatively high $Fe^{3+}/\Sigma Fe$ ratio ($Fe^{3+}/\Sigma Fe$=0.30) and very low $S^{6+}/\Sigma S$ ratio ($S^{6+}/\Sigma S$=0.06). The discrepancy of the oxidation state measured from iron and sulfur suggests that the oxidation state is affected by post entrapment processes or by the immiscibility process with carbonate liquid. In our case, we suggest that S speciation decoupling is attributed to silicate-carbonate immiscibility, and as such, low $S^{6+}/\Sigma S$ does not provide primary redox conditions in this system. The $Fe^{3+}/\Sigma Fe$ in melt inclusions yields magma redox conditions (fO_2) at around ΔFMQ+1.4 for phonolitic liquid corresponding of one of the most oxidizing conditions within the East African rift.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Crystallized Melt Inclusions in Quartz: tiny windows into magmatic evolution

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Key words: *Crystallized melt inclusion, cMIs, ChromaSEM-CL imaging, µXRF-EDS*

Crystallized melt inclusions (cMIs), or nanogranitoids, are tiny silicate melt pockets trapped in minerals like quartz during crystallization. They provide crucial insights into magmatic systems, across volcanic, subvolcanic, and plutonic environments, excluding volatile contents. As the rock cools, most inclusions crystallize, except very small ones (typically <100 µm for older systems), preserving mineral assemblages that reflect composition and conditions of original melt. Crystal-rich clots gained popularity, but is broader than cMIs. cMIs, along with phenocrysts, microphenocrysts, and their clusters, are useful tools for understanding magmatic evolution. Various analytical methods, including petrographic and ChromaSEM-CL imaging of phenocrysts like quartz (elemental mapping of phases) reveals fine-scale features and zoning patterns in quartz that provides context for trapping cMIs, providing insights into their composition and post-entrapment crystallization (PEC) processes. This technique helps identify post-entrapment alteration – modification of cMIs, providing insight into the preservation of the original magmatic signature. Optical imaging further complements this by offering detailed visual assessments of cMI integrity. SEM-EDS provides high-resolution imaging and elemental analysis of cMIs, revealing their detailed chemical composition. µXRF-EDS with LA-ICPMS allows for spatially resolved chemical mapping of cMIs and surrounding minerals, helping to identify compositional gradients and melt heterogeneities. Petrographic and compositional analysis of cMIs in quartz and phenocrysts reveal critical insights into magmatic processes like boundary layers, magma mixing, and fractional crystallization to cooling rate affecting relative crystallinity. Their compositional variations reveal magma evolution, tracing origin and changes from mantle to surface during ascent.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Magmatic volatile budget of the 2014 Tavurvur eruption at Rabaul volcano, Papua New Guinea

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Rabaul is a large caldera system characterised by a long and complex eruption history [1]. Rabaul's major active edifice Tavurvur places seventh overall in the world for SO_2 and CO_2 flux [2]. Even during inter-eruption quiescence, Rabaul was one of the highest outgassing volcanoes in PNG [3]. Since gas-rich magmas may drive violent explosive activity, reawakening of eruptions at Rabaul poses hazard and risk to thousands of people. In this study, we investigate the pre-eruptive volatile content of magmas involved in the 2014 eruption of Tavurvur and relate these findings to the characteristics of the eruption, such as volume, gas emissions, and triggering mechanisms. We conducted analyses of 105 melt inclusions for their volatile content as well as their major and minor elements. Volatile-trace element systematics show degassing of CO_2, SO_2 and H_2O out of the melt. The measured volatile contents thus do not record the primary volatile contents of the Rabaul magma. We used reverse fractional crystallisation modelling together with best estimates for the primary volatile/trace element ratios to calculate the primary volatile contents of the Rabaul magma. We compare our new data with global literature data for primary arc compositions. Finally, we use our new melt inclusion data to calculate the amount of SO_2 released during the 2014 eruption and compare our findings with satellite-derived observations. [1] Patia H et al. (2017) J Volcanol Geotherm Res 345:200-217 [2] Aiuppa A et al. (2019) Sci Rep 9:5442 [3] Carn S et al. (2017) Sci Rep 7:44095

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Origin and evolution of late discrete eruptive activity in long dormant volcanic province: the case of the Monts Dore stratovolcano (France)

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In a world where volcanic eruptions are among the most significant natural hazards to humanity, quiescent volcanic provinces play a unique role. The lack of a collective memory of past eruptions often encourages local populations to settle in these areas. However, long periods of quiescence can lead to the accumulation of energy at depth, potentially resulting in violent eruptions. To mitigate disaster risks and detect potential changes in activity, it is crucial to understand the past behavior of these currently quiescent volcanic provinces and develop effective monitoring strategies. Although the last major phase of activity in the Mont Dore volcanic province (France) occurred approximately 200,000 years ago, discrete eruptive events took place sparsely until 7,000 years ago. An unusual seismic swarm in 2021-2022 highlighted the gaps in knowledge regarding these late eruptive events, particularly in the vicinity of the seismic activity. To address this, a multidisciplinary approach combining the study of magmatic inclusions and pyroxene crystals is employed to constrain the architecture of the underlying magmatic system and to understand the evolution of magmas and fluids within it. Using this model, the chemistry of surface gaseous emissions is analysed to provide insights into the current state of the volcanic province. Seven sites were sampled, as well as two in the Chaîne des Puys (France) for comparison purposes. Whole-rock compositions range from basanite to trachy-basalt (43.0-46.8 wt.% SiO_2; 4.2-6.5 wt.% Na_2O+K_2O). First analyses of the melt inclusions seem to show a diversity of compositions that is at least as great.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Investigation of parental magma and eruption history of olivine-rich picritic crystal mush near Margi, Troodos ophiolite

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The Troodos ophiolite is one of the supra-subduction ophiolite complexes. Ascending from the base, the Troodos massif comprises tectonised harzburgite, layered intrusive rocks such as dunite, wehrlite, pyroxenite, and gabbro, followed by sheeted dykes and capped with extrusive rocks. Within the extrusive sequence, two distinct lava suites have been identified: (1) a relatively enriched suite comprising andesites, dacites and rhyodacite, called Lower Pillow Lavas (LPL), (2) a more depleted suite, basalt-basaltic andesite, corresponding to the former Upper Pillow Lavas (UPL). The area around Margi is within the UPL, which also contains unusually high crystal-rich (40 to 70 vol.%) picrites. This study aims to establish the parental compositions and eruption mechanisms of such crystal-rich picrites. To explore the parental magmas for the picritic bodies, we conducted fieldwork near Margi to (1) sample a suite of picritic and other olivine-bearing UPL rocks, and (2) observe field relations. Fieldwork was followed by electron beam microanalysis of a representative set of small picritic bodies to determine the crystal chemistry of olivine and abundant spinel inclusions in hosts. To probe the potential parental compositions of picrite, we modelled reverse crystallisation using the most primitive UPL glass compositions and applied a post-entrapment correction to glassy MIs for diffusive Fe loss using Petrolog4. Petrolog4 modelling constrains conditions of fractionation based on parental melt compositions modelled from olivine MI, revealing that crystal-rich magmas are likely formed by magma recharging and repetitive fractionation and concentration of olivine crystals within magmatic systems less than 0.5 GPa (i.e., ~12 km depth).

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

The complex magmatic plumbing system of the Miocene Laleaua Albă composite dykes (East Carpathians, NW Romania) revealed by crystal chemistry

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The Laleaua Albă magmatic complex (8.5-8.0 Ma) in the Miocene Gutâi Volcanic Zone (East Carpathian, NW Romania) mainly comprises two sub-parallel composite dykes both composed of an external zone of aphyric andesite and an internal zone of macroporphyric dacite. Complex mineralogy characterizes both rock-types: sanidine macrocrysts (up to 5 cm), large-sized plagioclase, quartz and biotite phenocrysts and smaller-sized amphibole and pyroxene as xenocrysts in dacites and much smaller-sized xenocrysts of plagioclase, amphibole and pyroxene and phenocrysts of plagioclase, quartz and biotite in andesites. Abundant microgranular gabbroic enclaves of various sizes (up to 90 cm) occur in the dacites. Similar pressure values for the high-Al, high-Mg amphibole and high-Mg clinopyroxene were obtained in all three lithologies, suggesting similar deep crystallization levels of 23-33 km from the mafic magmas. High An (70-90) plagioclase (phenocrysts in the enclaves, xenocrysts in andesites and antecryst cores in dacites) are comagmatic with the amphibole and clinopyroxene. Large-sized low An (28-40) plagioclase, strongly Ba-zoned sanidine alongside quartz and biotite suggests an evolved magma source, stalled in upper crustal reservoirs (probably a felsic crystal mush). This interpretation is supported by the chemical composition of melt inclusions in the quartz crystals of dacite (72-76% wt SiO_2) similar with the composition of the felsic enclaves (77% wt SiO_2) in the same dacite. The assumed architecture of the magmatic plumbing system consisting of deep (lower crust) and shallow (upper crust) magma reservoirs is consistent with the observed magma-mingling and -mixing features involved in the petrogenesis of the Laleaua Albă magmatic complex.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Crystals and melt inclusions as emissaries of magmatic plumbing systems

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The active Asal rift in the Afar region is an ideal site to study volcanism and magmatism associated with continental rifting. Our study examines the volatile element composition of magmas in the Asal rift segment, focusing on samples collected from various volcanic sub-segments within the active area, including a subset documenting the 1978 Ardoukoba eruption. Over 400 analyses of melt inclusions from plagioclase and olivine crystals reveal insights into the magma pre-eruptive volatile content. Using SIMS analyses, we quantified volatile components (H_2O, CO_2, Cl, S) to reconstruct the initial magmatic volatile content at reservoir depth. Combined with petrographic studies, field observations, major, trace and hydrogen isotopic composition, and new dating, our findings offer a comprehensive view of magmatic processes in the Asal rift, illustrating their spatial and temporal evolution. We assessed the contributions of primary (source composition, melting, differentiation) and secondary (degassing, contamination) processes to volatile composition variations. Our findings reveal that the Asal plumbing system extension has varied across time, both vertically and horizontally. We highlight cycles of magma differentiation over the range 1250-1050°C and degassing, accompanied by assimilation of hydrothermally altered rocks. In summary, this high-resolution dataset enhances our understanding of magma reservoir dynamics, providing new insights into the evolution, differentiation, and degassing of magmas in continental rift systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Evidence for adjacent yet discrete magma plumbing systems at Middle Sister and South Sister volcanoes, Oregon Cascades, USA

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Middle Sister (MS) and South Sister (SS) are two young (<50 ka), semi-coeval, and compositionally diverse (basaltic andesite to rhyolite) stratovolcanoes that are part of the Cascades Arc, USA. To understand how the plumbing systems of these geographically adjacent (within 5 km) volcanoes may or may not overlap, as well as illuminate magma origins, this study carried out a detailed investigation of mineral textures and compositions. A wide range of unit ages (ca. 47 to 14 ka), compositions (basaltic andesite to rhyolite), and localities (summit, east and west flanks) were selected in effort to identify any notable temporal, compositional, or spatial differences. An emphasis was placed on the overall more mafic MS system to better understand processes associated with mafic magmas and the deep crust, and to fill in existing knowledge gaps. Current findings suggest that mafic magmas at MS stall in the deep crust, where they interact with lower crustal melts, as has been interpreted for the older and monotonously mafic North Sister system. Mafic magmas at MS are also notable for their high-Ni olivine (in contrast to low-Ni olivine at SS), which is associated with crustal cumulates. Differences between the two systems extend into silicic magmatism, where MS magmas exhibit a higher alkalis trend (i.e., mostly trachytes at MS versus dacites at SS) and slightly more reduced conditions (i.e., ~ΔNNO-0.5 at MS versus ~ΔNNO+0.5 at SS). Cumulatively, these discrete characteristics support that separate processes are dominant at each volcano, as well as minimal interaction between the plumbing systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Magmatic interactions at the Three Sisters (Klah Klahnee) volcanic complex, central Oregon Cascades, USA

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This study utilizes compositions and textures of major mineral phases to identify distinct magmatic components in two lavas from the Three Sisters (Klah Klahnee) volcanic complex (TSVC) in Oregon, USA, to better constrain its plumbing system. The TSVC includes the adjacent Middle Sister (MS; primarily mafic-intermediate) and South Sister (SS; primarily intermediate-silicic), which are recently active (50–2 ka) Cascade Arc stratovolcanoes. The two lavas investigated here – the MS-affiliated dacite of Linton Creek (**dlc**, ~37 ka) and the SS-affiliated rhyolite of Separation Creek (**rsc**, ~25 ka) – present evidence for multi-magma interactions. Unit **dlc** hosts multiple populations of major mineral phases, as well as sparse amphibole pseudomorphs and reacted olivine; clotting relationships suggest three major magmatic components (mafic, intermediate, and silicic) and extensive compositional mixing between the mafic and intermediate components. Collectively, these components output a dacitic bulk composition. In contrast, **rsc** experienced two major recharge events, initially triggering partial mixing and then remobilization, recorded in multiple populations of major phases and extensively reacted olivine. Based on compositional differences recognized in MS-type magmas (i.e., more reduced conditions, high NiO versus forsterite trends in olivine, lack of amphibole) relative to SS-type magmas (i.e., more oxidized conditions, lower NiO versus forsterite trends, presence of amphibole), this work reveals that the MS-affiliated **dlc** is dominated by SS-type magmatic compositions, while the SS-affiliated **rsc** records recharge of a SS-type rhyolitic reservoir by MS-type mafic magma. These results are the first to demonstrate interactions between the MS and SS plumbing systems, which otherwise remain discrete.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Defining P-T conditions: multi-thermometric approaches to characterize the thermal evolution of the McDermitt Caldera plumbing system

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The McDermitt Caldera, a large peraluminous-peralkaline rhyolitic system that formed ~16 Ma during the onset of the Yellowstone hotspot track, has garnered attention for its Li-rich sedimentary deposits and geodynamic links to plume activity and Western US tectonics. The main volcanic activity that spanned 340 ka years has only received limited petrologic work. Here we integrate "TitaniQ" thermobarometry with additional thermometric methods to estimate P-T conditions of late-stage crystallization in both peralkaline and peraluminous rhyolites. By coupling this tool with cathodoluminescence imaging, XRF elemental mapping, and microscopy we link thermal evolution to textural information and shed light on late-stage magmatic processes and the pre-eruption history of the McDermitt system. Inferred temperature and pressure ranges of 790–900ºC were obtained using the calibration by Thomas et al. (2010). These results suggest a complex magmatic history characterized by significant temperature fluctuations and/or distinct rhyolitic magma bodies stored under variable conditions. However, the reliability of "TitaniQ" is debated due to uncertainties in aTiO2 in rutile-absent assemblages, though it provides accurate estimates when Ti-in-quartz is well-constrained. Using calibrations with aTiO2 values of 0.5–0.8 reveals a ±30ºC variability in temperature estimates. Complementary methods, the two-feldspar thermometer (Putirka, 2008), Fe-Mg exchange between biotite and melt (Holland & Blundy, 1994), and MELTS (Gualda, 2014), aim to address these discrepancies comparing different thermometric methods using other mineral phases in the rhyolitic assemblage. This comparative analysis evaluates thermometric precision and accuracy, identifies key influencing factors, and enhances thermobarometric applications in complex magmatic systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Experimental development of new oxybarometers based on V-partitioning between mafic minerals and hydrous silicate melts

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Redox conditions in magmatic environments control phase equilibria and the behavior of volatiles like sulfur. Understanding the interplay between oxygen fugacity (fO_2) and magmatic differentiation provides insights into the roles of magmatism and volcanic degassing in Earth's redox evolution. However, there are only a few studies on oxybarometric methods calibrated at elevated pressure and water content, conditions typical of magma differentiation at convergent plate boundaries. We conducted experiments (Pressure (*P*) = 200 MPa, Temperature (*T*): 1020−920 °C, logfO_2: -1 to +3.5 logΔFMQ) to develop oxybarometers based on vanadium (V) partitioning between mafic minerals and hydrous silicate melts. The results show that V partitioning is largely independent of *P*, *T*, and silicate melt composition (*X*). For olivine-silicate melt pairs, the V partition coefficient (D_V[Ol/melt]) is modeled using a sigmoidal regression equation: $\log fO_2(\Delta FMQ) = LOGX_0 - \log_{10}[(([(A_2-y)/(y-A_1)-1)]^2)^{0.5}]/p$, with $A_1 = -3.10 \pm 0.13$, $A_2 = 1.30 \pm 0.12$, $LOGX_0 = -1.98 \pm 0.25$, $p = -0.10 \pm 0.01$, and $y = \log D_V$[Ol/melt]. This equation reproduces fO_2 within a 2σ median error of one log unit over a wide range of *T-P-X*. This study expands previous data for olivine to lower temperatures and higher water activities, improving robustness and reducing calibration error. It also highlights the influence of fO_2 on fractional crystallization in intermediate magmas at subduction zones. The olivine-based oxybarometer is applicable to mafic volcanic rocks with suitable silicate melt inclusion-host mineral pairs for reconstructing magma reservoir redox histories. For more evolved magmatic systems, orthopyroxenes and amphiboles offer additional potential to similarly constrain fO_2.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Magmatic reservoir evolution of Lingshan rare-metal granite, South China

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The formation of highly evolved granites and associated rare-metal mineralization in South China is considered to be linked with the evolution of trans-crustal magmatic reservoirs. However, concrete examples illustrating this relationship are scarce. This study, based on field investigation, petrographic observation, bulk and in situ analyses, develops a comprehensive model of the shallow magma reservoir evolution within a trans-crustal magmatic system for the Lingshan Early Cretaceous pluton in South China. The pluton primarily comprises coarse-grained porphyritic granite in the central region, transitioning to medium-grained granite at the margins, with Nb-Ta mineralization associated with fine-grained granites and pegmatite veins along the periphery. The coarse-grained porphyritic granite represents a shallow magma reservoir. Recharge from high-temperature magma originating from the mantle and middle-lower crustal mush reservoir resulted in complex mineral structures and abundant intermediate-mafic inclusions within coarse-grained porphyritic granites. Medium-fine-grained porphyritic granites and fine-grained granites, as magma pockets within coarse-grained porphyritic granite, contain abundant rounded, coarse-grained quartz, indicating their origins from a reactive deep reservoir driven by high-temperature magmatic recharge. This process is critical for the growth, construction, and differentiation of shallow reservoirs. Within the coarse-grained granite, near-horizontal veins represent melts filtered from the mush reservoir, while near-vertical veins serve as channels for upward migration of the melt. Medium-grained granites along the margin gradually transitions to finer-grained near the contact with the surrounding wall-rock, indicating it represents an early-formed shell resulting from the initial crystallization of the magma reservoir, facilitating the ongoing evolution of the central mush and magma reservoir.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Magma plumbing system of Kirishima volcano revealed by helium isotopic ratio of olivine and pyroxene phenocrysts

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Noble gases are useful geochemical tracers for the origin of materials on and in the Earth. For example, since helium isotopic ratio, $^3He/^4He$, is $1.4\times10^{-6} \equiv 1\ R_A$ in the atmosphere, while $^3He/^4He = 8\ (\pm1)\ R_A$ in the convecting mantle, helium in fumaroles or hot springs is attracting attention as a monitoring tool for volcanic activity (*e.g.*,[1]). However, $^3He/^4He$ of melt inclusions in mafic phenocrysts, expected to reflect magma itself, is necessary for understanding a magma plumbing system. In this study, the noble gas isotopic compositions of olivine and pyroxene phenocrysts from the Kirishima volcano group in Japan were measured. The $^3He/^4He$ of olivines in the pumice of the Shinmoe-dake 2011 eruption was 7.43 (±0.06) R_A, while that of pyroxenes in the same pumice was 7.98 (±0.17) R_A. Although the olivines and pyroxenes are considered to be crystallized in deep and shallow magma chambers, respectively[2,3], $^3He/^4He$ indicate that melt inclusions in pyroxene have more mantle-like properties, which suggests the different crystallization timing. In addition, olivines in three lavas from Ohachi, erupted in 788, 1235, and 1350, respectively, had a high $^3He/^4He$ of ~8 R_A to reinforce that Ohachi lavas have a deeper origin[4]. [1] Padrón, E. *et al.*, *Geology* **41**, 539-542 (2013). [2] Suzuki, Y. *et al.*, *JVGR* **257**, 184-204 (2013). [3] Aizawa, K. *et al.*, *JGR Solid Earth* **118**, 198-215 (2014). [4] Kagiyama, T. *et al.*, *Bull. Volcanol. Soc. Jpn.* **42**, S157-S165 (1997).

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Evolution of rhyolite melt production on Lipari

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Making rhyolites in a volcanic arc requires a prolonged flux of primary magma to create thermal conditions conducive to extreme magma differentiation, a process which leaves behind a pile of crystal cumulates. How these processes operate, however, is often difficult to disentangle from complex volcanic systems with jumps in composition or eruptive style and overlapping edifices. On the island of Lipari (Aeolian Islands, Italy) rhyolitic volcanism developed following an extended magmatic buildup characterised by mafic to intermediate volcanism between ca. 267–81 ka. Then, following quiescence of ca. 40 ky, the magmatic system peaked by producing alternating dome-style effusive and explosive rhyolitic eruptions from ca. 43 ka to historical times. Eruptive centres progressively migrated from the S of the island, along the E coast, towards the N, where the most recent eruptions took place at 1243-1304 CE. This spatial development offers a unique opportunity to extensively sample the volcanic products, and through them understand the variable nature of the magmatic system developing under Lipari for the last ca. 40 ky. We will present new geochemical data probing the complete suite of rhyolitic eruptive products of Lipari, including glass and mineral compositions, revealing distinct spatio-temporal grouping of the magmatic products. New zircon U–Th disequilibrium ages will be used to refine the absolute time framework of eruptive activity. Our new data provide evidence of extensive fractionation (e.g. low Zr/Hf, Eu/Eu* in glass) en route to generating the rhyolites, indicating the existence of a heterogeneous cumulate body beneath Lipari.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

A clinopyroxene-based approach to unravel temporal changes in magma plumbing beneath La Palma, Canary Islands

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The architecture of magma plumbing systems may change over time, with significant implications for understanding volcanic behavior and improving monitoring efforts. This study focuses on clinopyroxene crystals to investigate the temporal evolution in historical times of the magma plumbing system beneath La Palma, in the Canary Islands. Samples from the 1712 El Charco eruption, the 1971 Teneguía eruption, and the 2021 Tajogaite eruption will be analysed using detailed in situ EMPA and LA-ICP-MS. These three eruptions are all characterized by the involvement of two distinct magmas: an amphibole- and pyroxene-dominated tephrite, and an olivine- and pyroxene-dominated basanite. Preliminary data on clinopyroxene cores from the 2021 Tajogaite eruption reveal three core populations, distinguished based on their textural and compositional characteristics. By characterizing the textural and geochemical characteristics of these eruptive products and using clinopyroxene-based thermobarometers, we aim to gain insights into the magmatic processes, storage conditions, and their temporal evolution underlying these eruptions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Mush system architecture and dynamics governing the Holocene eruptive history on the Ocean Island of El Hierro, Canary Islands

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Understanding the spatial and temporal distribution of mush-dominated systems feeding Ocean Islands (OI) is key to better constrain the magmatic processes ultimately leading to eruption. Here we present an integrated approach to unravel the dynamics of the magmatic plumbing system during the recent volcanic history at the OI of El Hierro (Canary Islands). Exhaustive sampling and detailed spatial, petrological, and geochemical characterisation were conducted on volcanic products, ranging from crystal-rich ankaramitic lavas to trachytic tephras, in 42 Holocene subaerial eruptions. Geochemical data, coupled with fractional crystallisation thermodynamic modelling and mass balance calculations, reveal that ankaramitic and porphyritic lavas with phenocryst modal abundances >10 vol% result from melt extraction and crystal accumulation. Aphyric to sub-aphyric products and porphyritic lavas with phenocryst modal abundances <10 vol% usually follow fractional crystallisation trajectories that start at ~10 wt% MgO. Minor trachytic eruptions are explained by periodic extraction of evolved melt from crystal mushes. We suggest that intricate interactions within a complex, vertically and horizontally heterogeneous, transcrustal mush-dominated system is the most likely scenario to explain the coexistence of endmember compositions, represented by ankaramites (>12 wt% MgO) and trachytes (~1 wt% MgO), which lie outside fractional crystallisation trajectories. The results allow us to put forward an updated conceptual model of the current plumbing architecture of El Hierro's volcanic system, highlighting the importance of understanding the processes that commonly govern magmatic, and especially mush-dominated plumbing systems worldwide.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Explosive Eruptions at Mount St. Helens: The Influence of Volatile Content in W Tephra Deposits on Eruptive Styles

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Pre-eruptive H_2O content impacts eruptive behavior as greater H_2O content is associated with more explosive eruptions. This study examines pre-eruptive H_2O content of W tephra deposits from three explosive eruptions (Wn, Wb, and Wd) during the Kalama period (1479–1482 CE) at Mount St. Helens using liquid-plagioclase hygrometry. Differences in pre-eruptive H_2O content could potentially explain shifts in eruption style and explosivity preserved by the W tephra deposits that are otherwise chemically similar. Electron probe microanalysis (EPMA) of plagioclase crystals shows a wide range of anorthite component for core compositions, but narrower for rim compositions, indicating that the W tephra eruptions were sourced from similar final depths. Preliminary hygrometer calculations show an overlap in H_2O content between the most explosive (Wn) and one of the less explosive eruptions (Wb). However, a distinctly lower H_2O concentration is indicated in the sequence's final eruption (Wd), which was also less explosive. H_2O solubility indicates the Wn and Wb eruptions equilibrated ~0.5 km deeper than the Wd eruption. These trends are supported by the prevalence of amphibole reaction rims in Wd samples that are missing in Wn and Wb samples. These results indicate that differences in pre-eruptive H_2O content can only partially explain differences in eruption behavior. Additional W tephra samples will be studied, including samples from the other major explosive eruption (We), to confirm these preliminary trends. These results have implications for forecasting future eruption behavior at Mount St. Helens and understanding what drives eruption style and intensity at a high-threat volcano.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Petrologic Mapping of the Magmatic Plumbing System Prior to the Most Recent Mount Hood Eruptions

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Understanding how volcanic systems change in response to magma recharge is critical, and changes in crystal composition can be used to track this response. Mount Hood is generally thought to erupt though cycles of mafic recharge, as has been noted for the Old Maid (OM) and Timberline (T) eruptions. However, it is currently unclear whether the subsurface magmatic recharge system responds the same was every time to recharge events. Here we use changes in plagioclase, a long-lived mineral in magmatic systems, composition from core to rim to investigate how the magmatic system of Mount Hood responds to recharge events. By combining anorthite composition and systems analysis, we can track magma migration in the subsurface in response to recharge for both OM and T eruptions. Our preliminary results indicate that all zoning types, normal, reverse, and complex zoning patterns, are present in both eruptions. However, when comparing core and rim compositions present in both eruptions, we note that each eruption has different peak core and rim compositions for the different zoning patterns, which indicates that different magmatic bodies were tapped in each eruption. This result is unexpected as past behavior of Mount Hood would suggest that eruptions tap into similar magmatic reservoirs. Further analysis of the connections between the OM and T eruptions. The possibility of different magmatic reservoirs being involved in different eruptions for Mount Hood has implications for hazard assessment for future eruptions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Remobilized MIs record storage conditions at Lopevi volcano (Vanei Vollohulu, Vanuatu, SW Pacific)

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Lopevi is an active basaltic-andesitic stratovolcano in the Vanuatu arc. Eruptions over the last 100 years have been characterized by near-constant degassing with intermittent explosive sub-Plinian tephra falls and effusive summit/flank lava flows. Geochemical heterogeneity between historic eruptive episodes (pre-1960, 1960-1980's, 1998-) has been attributed to decompression vs. flux melting in the mantle as well as variable assimilation fractional crystallization (AFC) occurring during transport and storage. These processes are thought to control magma dynamics and eruptive frequency at Lopevi; however, to date, research has focused on whole rocks/lavas. Melt inclusions (MIs) allow magmatic conditions at the time of entrapment within the host crystal to be determined and thus preserve information that may be lost in whole rocks due to later fractionation, mixing, and/or degassing. Investigating volatile, major, and trace elements in MIs will better constrain source, storage, and eruption processes at Lopevi. Here, we present the first analyses of olivine-, plagioclase-, and clinopyroxene-hosted MIs from tephras produced during the 1960-68 and 2002-3 eruptions. Textural evidence from accompanying lavas indicates that the two eruptive periods remobilized large phenocrysts from storage zones. Basaltic to andesitic MIs are partly degassed with H_2O 1-2.5 wt.%; CO_2 (glass) ≤ 480 ppm; S 100-850 ppm; Cl 960-2,350 ppm; and F 800-1,290 ppm. MI saturation depths of ~1-4 km for the 1960-68 eruption and 0.5-2.7 km for the 2002-3 eruption inferred from volatile solubility modelling suggest that the MIs were remobilized from distinct storage zones during each eruption.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Tracking the transition from magmatic to post-crystallization environment by coupling OH-defects and trace element analyses in quartz

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Quartz is a major constituent of felsic igneous rocks and can incorporate trace elements through isovalent and coupled substitutions. In this latter case, the involvement of hydrogen in the substitution mechanism can lead to the formation of hydroxyl dipoles (OH) with oxygen anions from the quartz lattice. Hydrogen can also be incorporated in interstitial, non-lattice-bound compounds. Physico-chemical parameters of the melt at the time of quartz crystallization regulate incorporation of trace elements and OH-defects formation, but post-crystallization processes might alter their budget and obscure the magmatic signal. We present the results of a coupled OH and trace elements systematic study in quartz from the silicic intrusive and eruptive products of a Permian transcrustal magmatic system (Sesia Magmatic System). Each grain was analysed using FTIR spectroscopy to investigate hydrous defects both qualitatively (OH species) and quantitatively (OH content), followed by the determination of trace elements content via LA-ICP-MS analysis. Results indicate systematic variations: (1) intrusive quartz shows decrease in Ti and increase in total water content (1-25 ppm H_2O) with differentiation; (2) volcanic quartz displays variable Ti and water contents (2-14 ppm H_2O) comparable to intrusive units; (3) in both intrusive and eruptive units, lattice-bound Al-specific defects dominate over non-lattice bound Li-specific defects, except in a porphyritic dike showing evidence of fast cooling. These observations suggest that, in absence of fast cooling, only slow-diffusing elements and molecules (Al, Ti, AlOH) can preserve the primary magmatic signal in quartz, suggesting caution in interpreting fast-diffusing elements (Li) and compounds (LiOH) as petrogenetic indicators.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Magma Storage Conditions Beneath Krakatau, Indonesia: Insight from Geochemistry and Rock Magnetism Studies Aditya

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Krakatau volcano is characterized by cyclic phases of growth and destruction of the edifice. A volcanostratigraphic study identified three eruptive periods: Old, Young, and Anak Krakatau. The Old and Young Krakatau periods ended with the first and second Caldera Forming Eruption respectively. Due to its permanent activity and edifice evolution, Krakatau poses a high risk on the surrounding inhabited islands. In this study, we combined geochemistry, rock magnetic, and petrology to infer the evolution of magma storage conditions from Old to Anak Krakatau periods. This study is the first to report on the chemical and rock magnetic characteristics, as well as storage system conditions of Old Krakatau and its relation to the ongoing evolution of Krakatau. Our data show that:1) Old and Young Krakatau magma storage regions are shallow (within the upper 3 km), contain more differentiated magmas, from which the Old Krakatau magmas may be less oxidized and had lower temperatures than Young Krakatau;2) Anak Krakatau magma storage is deeper (up to 26 km), less differentiated, and erupted hotter but more reduced compared to Old and Young Krakatau. The Old and Young Krakatau lavas chemical characteristics are included at maturation phase (pre-CFE), whereas the Young Krakatau pumice samples were the product of the second CFE. Lastly, the post-second CFE activity of Anak Krakatau is currently in an incubation phase and represented by mafic products. Knowing that the volcano has experienced maturation and CFE phases in the past, the current Anak Krakatau may evolve to those phases in the future.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Magmatic Cl-H2O contents, fluid extraction and porphyry fertility: Evidence from zircon and its apatite inclusions

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Formation of economically significant porphyry deposits requires vast amounts of magmatic volatiles (H_2O, Cl, and S). However, the conditions enhancing efficient trans-crustal delivery of volatile fluxes remain unclear. In this work, we investigate the water contents of zircon and volatile compositions of zircon-hosted apatite of the co-sourced pre-ore (ca. 110 Ma), syn-ore (ca. 103Ma), and post-ore (ca. 97 Ma) intrusions in the Zijinshan porphyry-epithermal ore field (ZOF) in South China. Although geochemically similar, zircon-hosted apatite inclusions from the syn-ore porphyry yielded highly variable Cl (0.14-2.94 wt.%) and F (0.04-3.37 wt.%) contents, whereas the pre-ore and post-ore apatite populations show restricted halogen compositions (0.62-2.70 wt.% Cl, and 0.41-1.56 wt.% F). Numerical modeling of apatite evolutionary trends suggests that the syn-ore magma had the highest initial melt H_2O (5.08 wt.%) and Cl (2035 ppm) contents, reaching volatile saturation at ~215MPa and exsolving fluids with a salinity of ~7.0 wt.% NaCl eq., consistent with zircon data. In comparison, pre-ore and post-ore magmas had lower initial H_2O (3.6-3.9 wt. %) and Cl (890-1370 ppm) contents, saturating at ~80-166 MPa with less saline fluid (2.3-4.7 wt.% NaCl eq.). We suggest that the syn-ore saturated conditions optimize Cl-Cu extraction efficiency, promoting the formation of connected ore-fluid networks and fluxes that are favourable for porphyry mineralization. Given the lack of direct syn-ore mafic magma input, we propose that fluids derived from underplating mafic magmas serve as the dominant volatile accumulation mechanism for porphyry mineralization in the ZOF.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Bi-directional flow of magma recorded by melt inclusion morphology

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Melt inclusions (MIs) in volcanic rocks are commonly used to probe magma composition. However, less information was extracted from MI morphology which can vary with crystal growth rate and pre-eruption conditions. We investigate this using a centimetre-sized anorthoclase megacrystal from Mount Erebus, Antarctica ([1]) and phonolitic MIs of varying morphology. Similar megacrystals from Erebus were suggested to grow at 950 ±25 °C and variable pressures and travel a few cycles between the magma reservoir and lava lake before eruption (e.g., [2]). We analyse the morphology (e.g., area, aspect ratio, roundness) of MIs (n = 687) across the megacrystal using *ImageJ* software. We find that aspect ratio is a key feature that links the MI morphology to the anorthoclase composition (e.g., orthoclase content). This can be explained by a strong pressure dependence of the growth rate and orthoclase content of Erebus anorthoclase ([2]). To investigate the number of convective cycles witnessed by the megacrystal, we divided it into elliptical zones with the same centre but different major-minor axes and applied a statistical test to assess the difference between zones. We find that the innermost zone is distinct from those at the crystal mantle but similar to zones closer to the rim. Combined with pressure estimates from the anorthoclase, these imply at least one convective cycle before the final ascent to the surface. Our findings show that MI morphology variability can be linked to changes in crystal growth rates and pre-eruption conditions. [1] Li et al. (2023). [2] Moussallam et al. (2015).

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Pre-eruptive magmatic processes leading to the Puig Jordà monogenetic eruption (Garrotxa Volcanic Field, Spain)

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Petrological studies of monogenetic eruptions have proven that magmas do not always ascend directly from the mantle but instead involve processes like magma mixing or assimilation of crustal material. This challenges traditional views, especially in regions like the Garrotxa Volcanic Field (GVF), where past eruptions were believed to result from direct magma ascent, supported by the presence of mantle xenoliths in some volcanoes. To explore this hypothesis in the GVF, we conducted a petrological study of the Puig Jordà monogenetic volcano. Our investigation focuses on olivine, clinopyroxene and spinel crystals, revealing evidence of magma arrest and mixing processes prior to eruption. Thermobarometric modelling suggests rapid magma ascent from a deep zone at ca. 1000-1100 MPa and 1200-1240°C, followed by the incorporation of previously emplaced magma batches located at 500-900 MPa and 1140-1190°C, and a final stage occurring at shallow crustal levels with lower temperatures (ca. 1110°C). Our new findings indicate that shallow and transient magma reservoirs exist in the GVF, and have significant implications for the duration of pre-eruptive unrest in the GVF and, hence, for the interpretation of monitoring data in the future. Furthermore, our study has revealed that either the traditionally associated Bosc de Tosca lava flow is not sourced from this volcano, or that the eruption involved the emission of two distinct magmas, leading to the formation of pyroclastic deposits and the lavas. This work was financed by the grant PID2023-151693NA-I00 (funded by MCIN/AEI/10.13039/501100011033) and by the Parc Natural de la Zona Volcànica de La Garrotxa.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Tracing the evolution of magma chemistry during the Archean using apatite

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Many aspects of Earth's early evolution remain enigmatic, one of them being the nature of the creation of the first felsic crusts. Remnant lithologies from these ancient times are rare and usually not pristine, which hinders greatly the interpretation of their primary compositions. We studied apatite inclusions in Archean (4.0-2.5 Ga) zircon crystals to better understand the petrogenesis of their parental magmas. Zircon crystals are well known for their resilience to metamorphic events, which, added to their capacity to be robustly and precisely dated, makes them the most robust host for primary inclusions. Apatite incorporates large quantities of rare-earth (RE) and volatile elements (F, Cl, OH) that allow to check for their chemical integrity and to trace the magmatic environments of their formation. We measured REE and major element concentrations in apatite inclusions from the Karelia Craton (Russia, Finland), the Wyoming Craton (USA) and the Slave craton (Canada) to cover more than 1.5 Gy. In this contribution, we will discuss the results of the chemical composition of the apatite grains coupled with U-Pb LA-ICP-MS dating of the host zircon crystals, in respect to the formation and volatile contents of these early felsic rocks at a local and global scale.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Does melt (dry or hydrous) influence cation diffusion in plagioclase?

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Plagioclase feldspar forms in most magmas. Its chemistry is sensitive to T, P, and melt composition (including H_2O), making it an important tool to track magma storage and differentiation conditions. It is also exploited to track timescales of magmatic processes using diffusion chronometry. A recent investigation of cation diffusion in olivine has shown diffusivities to be potentially sensitive to the presence of melt around the mineral. In this study, we test whether (1) the presence of melt or solids around plagioclase and (2) the presence/absence of substantial H_2O in the system have any bearing on diffusion rates of Mg, Fe, or Sr. We carried out experiments in gas-mixing and IHPV furnaces at conditions of 0.1–85 MPa, up to ~3.5 wt.% H2O, and 1025-1080°C. Two experimental geometries were employed: plagioclase seeds cut into parallelepipeds surrounded by basaltic-andesite or mineral powders (augite, SiO_2, diopside, plagioclase), or plagioclase crucibles filled with powder. Preliminary results show little sensitivity of Mg to the type of diffusant source (powder vs. melt), to crystallographic orientation, or to H_2O in the system. Mg diffusivities are consistent with prior studies (Van Orman et al. 2014). Fe diffuses faster than Mg and therefore has the potential to resolve shorter timescales difficult to record with other elements. Importantly, our experiments all resulted in gradients in Ca-Na not accompanied by gradients in Al-Si. These gradients are often longer than gradients in Mg, implying that Ca and Na may be considerably more mobile than previously recognized.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Using petrology to constrain the onset and migration of the Lesser Antilles subduction: Insights from zircon and amphibole from Saint Martin

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The island of St Martin is unique owing to its outcrops of both volcanic and plutonic rocks and a conspicuous sequence of volcano-sedimentary deposits, providing a unique archive of the onset of volcanism in the northern portion of the Lesser Antilles. The island of Saint Martin hosts a significant portion of Eocene and Oligocene volcanism missing from the rest of the volcanic arc. Using Laser Ablation Inductively Coupled Plasma Mass Spectrometry, we have dated and analysed trace elements in zircons from 6 key samples and obtained ages from ~52 to 23.2 Ma, giving us an unprecedented 30 Ma of magmatic evolution. Using an Electron Probe Microanalyzer, we have collected major element concentrations in amphiboles from the same 6 key samples and in gabbroic cumulates found on Saint Martin. We used the thermobarometer and chemometer of Higgins et al. (2021) to trace the evolution of the architecture of the magmatic plumbing system over its entire duration. We find that the system went through changes in the melt crystallization temperature, with increasing and decreasing trends through time. The system's pressure first increased until the middle Eocene and then decreased in the Oligocene. The amphibole thermobarometry results correlate well with zircon geochemistry from Saint Martin, which also suggests similar temperature trends. We will present an interpretative framework linking the temporal evolution of zircon geochemistry and thermobarometric estimates to the geodynamic evolution of the northern portion of the Lesser Antilles.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Centennial volcanic cycle revealed by volatiles in melt inclusions at Cotopaxi volcano, Ecuador

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Cotopaxi volcano is one of the most active volcanoes in Ecuador and the most dangerous in the country. It has experienced at least four VEI 4-5 eruptions in the last 500 years (i.e., 1742-1744, 1766-1768, 1853 and 1877). We have analyzed major and volatile contents of melt inclusions hosted in plagioclases (An_{46-79}) and clinopyroxene ($DiHd_{0.73-0.80}$) of the four major eruptions mentioned above and one occurring in the 10th century. These eruptions were chosen because they represent the different eruptive scenario for this volcano. Uncorrected melt inclusion compositions (i.e., 58-72 wt.% SiO_2) follow the same trend formed by whole rocks and matrix glass in silica versus MgO, CaO, and Al_2O_3 plots. The mean volatile contents of all studied melt inclusions are 638±322 for S, 1273±332 for Cl, 667±144 for F, and 2.15±0.98 wt.% H_2O. Interestingly, each eruption displays its own geochemical signature. Altogether, the studied eruptions reveal a long-term volcanic cycle at Cotopaxi volcano, characterized by: (1) the differentiation of magma in a deep chamber during a period without major eruptions, (2) highly explosive unrest and eruption of a large volume of evolved magma, (3) intrusion of mafic, volatile-rich magma leading to explosive activity, (4) predominantly effusive eruption of the previously intruded mafic magma, and, finally, (5) the closure of the cycle with the differentiation of the remanent magma. These findings could enhance the ability to forecast eruption styles in the future.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.1: Crystals and melt inclusions as emissaries of magmatic plumbing systems

Allocated presentation: Poster

Trends in crystal chemistry recorded across the Alaska-Aleutian volcanic arc

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The chemical composition of mineral phases reflects both the crystallization conditions and composition of melt they crystallize from. Crystal growth can thus record a diversity of melt compositions and conditions reflecting complex magma plumbing and crustal storage histories, while glass reflects the final magma amalgamation preceding eruption. Trace elements, especially incompatible trace element ratios, have particularly strong potential to capture melt compositional history at a volcano even from the crystal record of a single sample. Here, we take a broad look at mineral compositions across the entire Alaska-Aleutian volcanic arc, looking thus far at amphibole from 17 samples at 12 volcanoes. We use amphibole trace-element compositions to estimate the compositions of host melts from which they crystallized. The results extend to less and sometimes more evolved compositions than captured in their host sample bulk or glass composition. These trends are found in samples with a range of bulk compositions including basalts, andesites, and rhyolites. Sr diffusion profiles can provide further context to these preserved compositions within the zoning profiles of individual crystals. Other phases have potential to record complementary information. Plagioclase and pyroxene, while more limited in utility with trace element partitioning, are ubiquitous phases found in nearly all arc volcanic samples. Fe-Ti oxide pairs provide a relatively robust tool for calculating eruption temperature and fO2. Our purpose here is to show how integrated arc-wide studies of disparate mineral composition can provide a powerful complement to similar compilation efforts for whole rock and glass compositional data.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Talk [Invited]

Protracted assembly of the magmas feeding the 1783-84 Laki fissure eruption, Iceland

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The A.D. 1783-84 Laki eruption in Iceland was one of the largest basaltic fissure eruptions in historical times and serves as one of the best small-scale modern analogues of a flood basalt eruption. Understanding the timescales over which large volumes of eruptible magma are assembled remains a key challenge in Earth sciences and volcano monitoring. We combine textural observations, microanalysis (EPMA and SIMS) and diffusion chronometry of high-anorthite (An_{85-90}) plagioclase crystals from Laki eruptive fissure VII to gain new insights into timescales and magma storage conditions underneath Grímsvötn. We identified three plagioclase subpopulations based on crystal zoning and Mg trace element geochemistry. Type I plagioclases have oscillatory zoned mantles and core Mg contents in equilibrium with an evolved interstitial mush liquid at a temperature of 1120 °C. 3D diffusion modelling indicates a minimum residence time for Type I crystals of 500 years. Type II and Type III plagioclase crystals have simple zoning and exhibit major Mg disequilibrium in their cores representing melt replenishment events approximately 100 years to 150 days before eruption. This corresponds well with a cyclical increase in eruptive activity at Grímsvötn central volcano. Combined, our observations and modelling results suggest that the magma reservoir that fed the Laki eruption grew incrementally over hundreds to thousands of years with regular replenishment by new melts supplied under the Grímsvötn volcanic system. These replenishment events may have been closely associated with stress release events in southern Iceland. This creates an interesting framework in which monitoring strategies can be devised.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick… Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Talk

The fluid dynamics of magma mingling and mixing during dyke propagation and eruption: Insights from analogue experiments

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Volcanic fissures can erupt magmas which have a range of physical and chemical properties that suggest mingling and mixing between distinct magma reservoirs. The timing and location of mingling/mixing however is uncertain, with interactions either happening within sill-like reservoirs at depth, between reservoirs, during transport to the surface within a dyke, or a combination of all these. Here, we use analogue experiments to explore the fluid dynamics of magmas mingling and mixing during ascent within a growing dyke and discuss how these impact chemical and petrological expressions. An array of Newtonian immiscible and miscible pairs of fluids with differing density, representing magmas of different compositions, were injected sequentially at low or high volumetric flux into a solid, elastic body (crustal analogue) to create experimental dykes. Photographs were captured in the planes along the dyke strike and across the dyke thickness and processed to measure dyke tip velocity and qualitatively assess the extent of mingling and mixing. The experiments were repeated using particle image velocimetry (PIV) to calculate flow velocities within the dyke. Our results show an internal high-velocity jet structure and recirculating flow forms during mixing, whereas low-velocity uniform upwards flow forms during mingling. We find that a higher flux promotes more effective mingling and mixing, and this is associated with greater dyke tip propagation velocity and greater internal velocities. We discuss our experimental results in terms of magma recharge events, evolving properties of eruptive products, and natural Icelandic fissure systems that display chemical and physical interaction of distinct magmas.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Talk

Complex plumbing and conduit control on the eruptions of the last 30 years at Popocatepetl Mexico revealed by multiparameter monitoring

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Popocatepetl volcano that is 37 mi from Mexico City and stands 5452m asl, started erupting in 1994 and since then has had varying magma compositions and mineral assemblages that change within days. From 1996 until 2019, over 85 successive domes were formed and destroyed in the crater producing mostly glassy ash particles. Vesicular clasts contain 2-7 MgO wt% and 56-66 SiO_2 wt%. Different magma batches ascend from the base of the crust to shallow depths and mix with different magma bodies in short episodes. Pyroxene geobarometry indicates that magma rises from depths of 7, 13**,** 25, 30, 35 and 43 km. Larger explosive events in 1997, 2001, 2013, 2019 and 2023 were associated with influx of deeper more gas-rich magma days before. Negative magnetic anomalies, increases in harmonic tremor, and B and PCO_2 in the spring water preceded the larger more mafic events and allowed us to advice Civil Protection weeks before. Shallow stagnation in the conduit caused small plugs to form since 2019 until new magma batches with changing compositions pushed them out. The first domes contained abundant forsteric olivene that was replaced as a mafic end-member by Mg-rich orthopyroxene after the first years but the evolved hybrids continued to vary in the larger events. Seismic activity is concentrated down to 11km under the crater and to the southeast of the crater We consider that the plumbing system is probably made up of a series of sills and dikes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Talk

Kinetics of mafic magma transfer and destabilization of the deep plumbing system in monogenetic volcanic provinces (Chaîne des Puys, France).

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Volcanism results from magmatic processes that are governed by the plumbing system architecture and the timescales of magma migration. While large stratovolcanoes are believed to be fed by transcrustal magmatic systems with crystals and melts erupted from a range of reservoir depths, mafic monogenetic volcanoes are commonly considered to be fed directly from the mantle, with strong implications on the timescales of unrest and magma transport to the surface. Here we address these issues by a petrological study of six scoria cones representing the mafic endmember of the Chaîne des Puys (France). This monogenetic volcanic province dominates the Clermont-Ferrand agglomeration (400,000 inhabitants), with the last eruption occurring only 6.7 kyr ago. We investigated the composition and textures of several hundred clinopyroxene and olivine phenocrysts and applied crystal system analyses, and diffusion chronometry. We found that scoria cones were fed by two to three magmatic reservoirs and that crystal circulated between them before eruption at a range of timescales. We propose that magmas migrate repetitively from the deepest basaltic reservoir (R1; ~25 km depth) partly in the mantle, to slightly more evolved and shallower reservoirs (R2) where they interact with the host magma before eruption onset. Occasionally, magmas from R2 migrate and interact with trachy-basaltic R3 reservoirs (~18 km). The timescale of eruptions triggering when magma is transferred from R1 to R2 ranges from about six months to a few years, while it ranges from about one week to five months for magma transfer from R2 to R3.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Talk

Slow and Steady or Sudden? Integration of Crystal Records and Geophysical Signals prior to the 2008 eruption of Okmok Volcano (AK)

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One physical model for eruption is reservoir inflation reaching a critical threshold, successfully employed to forecast Axial Volcano's 2011 eruption [1] and to hindcast Okmok Volcano's 2008 eruption (OK08) [2]. However, OK08 was also preceded by a five-hour seismic swarm, extending to ~16 km depth [3]. Was OK08 driven by slow and steady inflation or a sudden event? To answer this question, we investigated OK08 melt inclusions (MIs) and olivines to constrain the depth and timing of magmatic events. A bespoke piston-cylinder technique was used to resorb CO_2 in shrinkage bubbles. Some restored MIs contain > 1700 ppm CO_2, reflecting volatile saturation pressures (~380 MPa or ~16 km depth) that coincide with the deepest seismicity during the 5hr swarm. The high CO_2 MIs also have unusual compositions (CaO > 11 wt%) only found in ash erupted within the first hours of eruption [4]. The complete lack of zonation in some olivines that are otherwise out of equilibrium in host melt requires rapid transport (< days), while other olivines record mixing events that occurred days to years prior to eruption. Thus, the 5hr precursory seismicity corresponds to a deep and chemically distinct magmatic input, which forged a new vent from that which hosted the prior century's eruptions. The OK08 eruption was triggered by a sudden recharge event, distinct from earlier magmatic inputs events (largely aseismic but driving inflation) that may have nonetheless primed the system for eruption.
[1] Chadwick 2022. [2] Albright 2019. [3] Garza-Giron 2023. [4] Larsen 2013.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Talk

Caldera collapse associated with rapid deglaciation at Villarrica (Rukapillán) volcano from revised chronostratigraphy

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We explore relationships between ice loading and changes in magma composition and eruptive rates at Villarrica (Rukapillán) and elsewhere along the Andean Southern Volcanic Zone. At Mocho-Choshuenco volcano, mafic eruptions before and during the Last Glacial Maximum (LGM, 35 to 18 ka) were followed by silicic eruptions, including caldera-forming rhyolites at 13.5 and 11.5 ka. In contrast, Rukapillán has erupted basaltic andesite during its 180 kyr history, including the 10 km^3 Licán Ignimbrite at 16.8 ka, for which the associated caldera has remained obscure. The magma reservoir beneath Rukapillán has responded differently during and after rapid deglaciation than the silicic reservoir beneath Mocho-Choshuenco. To examine the role of ice loading 35-18 ka and rapid unloading 18-16 ka, we have determined eruptive ages using $^{40}Ar/^{39}Ar$, ^{3}He, and ^{14}C methods. During the LGM, basaltic lavas displaying ice-contact textures at 1000-1600 masl yield $^{40}Ar/^{39}Ar$ dates of 21-23 ka. The rim of a 4.2 km caldera preserves truncated lavas $^{40}Ar/^{39}Ar$ dated at 18-16 ka. Thus, ice during the LGM was >1.5 thick, and immediately after its retreat, caldera collapse was coeval with the eruption of the Licán ignimbrite. We hypothesize that glaciation increased lithostatic stress and that the rapid decrease in stress during ice retreat enhanced volatile exsolution, pressurized the magma reservoir, and subsequently produced an explosive eruption. The rapid response of Villarrica to ice unloading may reflect the low viscosity of basaltic andesitic magma that permits rapid volatile exsolution and bubble ascent in contrast with rhyolitic magmas erupted 3-5 kyr following deglaciation at Mocho-Choshuenco.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Timescales and rates of magma ascent using 3D-CSD in lava flows of the Mangawhero Formation, Mount Ruapehu, New Zealand

Silvia Catalina Moreno Alfonso*[1], Geoff Kilgour[2], Georg F. Zellmer[1], Satoshi Okumura[3], Yoshiyuki Iizuka[4], Masahiro Yasutake[5], Kentaro Uesugi[5], Stuart Mead[1]

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Previous studies in the Tongariro Volcanic Centre tephra (<10 kyr) have yielded residence times between 2 to 4 days and ascent rates up to 9 cm/s. One of the volcanic centers generating tephras is Mount Ruapehu, an edifice built by massive lava flows over the last 250 kyr. Determination of the residence times and ascent rates of lava flows is therefore critical. The Mangawhero Formation is a lava flow unit of Mount Ruapehu composed mainly of andesites with plagioclase and two pyroxenes, emplaced between 50 and 15 kyr. Using pyroxenes from 9 lava samples of the Mangawhero formation, we determined the crystal size distributions (CSD) and subsequently the residence times using the slope of the CSDs and a known growth rate for orthopyroxene, obtaining residence times between 2 and 9 days. Further, plagioclase and pyroxene crystals were analyzed using EPMA to obtain their compositions and determine the P-T-H_2O conditions using a combination of thermobarometry, hygrometry and MELTS modelling. We found that the magmas had water contents up to 3 wt.%, and resided at pressure up to 2.14 kbar and temperatures up to 1075°C. Lastly, using the maximum pressure obtained through melts modelling, we determined the maximum depth that in combination with the residence times provided information about the maximum ascent rates, ranging between 2 and 3 cm/s. This information will be crucial in determining the difference in the eruption style of the volcanic products.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick… Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Integrating timescales from diffusion modeling in crystals to geophysical monitoring data at a large submarine volcano (Fani Maoré, Mayotte)

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A challenge of volcano monitoring is to link near-real-time observables, e.g. seismology, deformation, or gas emission, to deep magmatic processes, their variation over time and their relevance in eruption triggering. A key method to understand magmatic processes and their timescales with respect to eruption is to look at erupted products and apply diffusion geochronometry to zoned crystals. Thus, linking timescales from diffusion modeling to signs of unrest measured at Earth's surface has the potential to enhance eruption forecasting. The largest submarine eruption monitored to date that led to the birth of Fani Maoré (FM) volcano offshore Mayotte Island (Comoros Archipelago) is an excellent candidate to develop this approach. Multiple oceanographic cruises during this 2.5-year-long basanitic eruption (2018-2020) provide a unique multi-disciplinary dataset that can be used to better understand pre-eruptive magmatic processes. Reversely zoned olivine crystals in late erupted units suggest that basanitic magma interacted with a more evolved reservoir during ascent. Diffusion modeling in olivine, shows that this magma stalled below the second reservoir leading to progressively longer timescales of magma interaction as eruption continued – from 1-3 months for the first flows, up to 17 months for later lava flows. Through regression analysis we can constrain the first magma interaction to April 2019. A year later, eruptive activity declined in March 2020. Both time periods are reflected by changes in seismic activity and a decline in deformation at FM, which suggests that the deep magmatic processes recorded by diffusion chronometry are recorded by monitoring parameters at the surface.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Characterization of magmatic storage conditions following a mafic recharge event

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Understanding the long-term storage conditions of silicic magma in the Earth's crust is crucial for interpreting volcano monitoring data and predicting volcanic eruptions. Recently, the volcanology community has been interested in the timescales over which large volumes of detectable magma exist in the crust before eruption, and how magma mixing or mafic recharge may trigger volcanic activity. We study mafic enclaves, which link the mixing process and the archive for transient thermal conditions in a unique way as they are also inherently the agents of recharge. This study aims to assess how long magmatic systems reside in a state of elevated storage temperature following a magmatic recharge and what the temperatures involved during a recharge are. By answering these questions, we can on the one hand gain insights into the timescales of elemental diffusion, which constrains the rates of mixing and ascent before and during eruption. On the other hand, our results can provide constraints for dynamic models that explore mixing and hybridization through a first-order documentation of the temperature variance in a system. To capture the response of the system to the transient thermal signals on timescales of months to decades, we are applying a Magnesium-in-plagioclase thermometer and geospeedometer on mafic enclaves from the Chaos Crags (Lassen Volcanic National Park), that have clinopyroxene-plagioclase pairs preserved and thus allow us to ignore issues related to a moving boundary by acting as a diffusion-couple.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Inherited argon preserved in plagioclase antecrysts in the Lesser Antilles allow to unravel residence times between reservoir remobilization and eruption

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We study lava domes from the Lesser Antilles, in which the plagioclase cargo yields K-Ar ages 2 to 3 times older than the eruption ages. The textures and chemistry of plagioclase antecrysts reveal several events related to the injection of mafic magma and crystal mush remobilization. The age difference is explained by the fact that the antecrysts, remobilized by an incoming magma prior to eruption, contain inherited radiogenic argon that accumulated in the crystals by K radioactive decay while crystals were in cold storage. The timescales between intrusion and eruption were too short to heat up the antecrysts above their closure temperatures for argon, and therefore were not completely reset. We use this age difference to calculate timescales between magma mixing and eruption using an innovative approach that combines multi-grains total fusion K-Ar ages and step-heating $^{40}Ar/^{39}Ar$ dating of plagioclase, argon diffusion modelling, and finite element diffusion modeling of Mg, in samples for which eruption was dated independently. We have calculated that the age differences observed require residence times of 10 to 100 years between the injection of a new magma and its eruption. This can be related to changes in the volcano's morphology due to large scale flank collapse or explosive events having remobilized the plumbing system relatively quickly. Our approach provides constraints on the timing between magmatic intrusion or flank collapse and explosive eruptions. The rapid remobilization and eruption of upper-crustal magmas indicates that the onset of eruptions at Lesser Antilles volcanoes may occur with little warning.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Thermomechanical modelling of stress around dyke tips

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Magma propagates to the surface, eventually feeding volcanic eruptions, through pressure-driven fractures. However, not all dykes reach the surface; many of them become interrupted in their ascent. Whilst there has been focus on the importance of host rock mechanical properties on dyke arrest, temperature effects are often neglected. However, magma may locally disrupt temperature fields leading to thermal expansion or contraction and hence generate thermal stress and in some cases brittle thermal fractures. In this work, we use a thermomechanical approach to investigate potential thermal stress perturbations around dyke tips. The objective of the present study is to understand the role of thermoelastic parameters in signatures generated during dyke emplacement and cooling and consider how this may influence dyke growth dynamics. For this purpose, a two-dimensional nonlinear thermoelastic transient model was implemented using the finite element method. Results show that the most sensitive variables of the model are the modulus of elasticity and coefficient of thermal expansion, in equal magnitude. Furthermore, it was found that the thermal stresses produced in the direction of propagation of the dyke suppressed the tensile stress generated in purely elastic models, potentially changing the dominant fracture mechanics between a purely tensional crack opening to a hybrid displacement near the tip of the dyke as the surrounding rock was heated. This has implications for the amount and style of related seismicity. The fracture propagation mechanism may allow arrested dykes to continue their propagation once the thermal stresses have overcome the strength of the rock.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

From hours to centuries: using DiffSim to determine magmatic timescales in diverse mineral phases

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DiffSim is a new software tool that enables magmatic timescale calculations via diffusion chronometry modelling of major elements in solid phases such as olivine, orthopyroxene, titanomagnetite, and melt. Available as executable freeware, DiffSim makes it accessible for researchers and students to use diffusion chronometry for precise insights into crustal processes. In addition to calculating precise magmatic timescales, DiffSim incorporates error propagation, offering maximum and minimum timescale estimates to enhance the reliability of its results. DiffSim models diffusion based on the exposed crystal orientation, requiring the plunge, trend of the (001)-axis, and 2D section angle. Additionally, users define the initial composition-distance profile, time resolution, and intensive parameters (e.g., temperature, pressure, oxygen fugacity). We tested DiffSim in two case studies within the Southern Volcanic Zone of the Chilean Andes: the 2015 eruption of Calbuco and the Neltume tephra of Mocho-Choshuenco (~11,500 years ago). Zoned crystals of titanomagnetite, olivine, and orthopyroxene in these samples yielded timescales ranging from hours (Calbuco), which likely reflect the eruptive trigger, to several years (Mocho-Choshuenco), indicating residence in an upper crustal reservoir.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Monthly timescales of magma ascent and eruption triggering in two reservoirs beneath Hornopirén volcano, Southern Volcanic Zone

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The Southern Volcanic Zone (SVZ), the most active volcanic region of the Andes, is characterised by the Liquiñe-Ofqui Fault Zone (LOFZ), a major NS trending structure, which extends ~1200 km long. Small eruptive centers are commonly built over the LOFZ, including Caburgua-Huelemolle, Fui Cones, Carrán-Los Venados, and Cayutué-La Viguería. An exception is the Hornopirén composite volcano (41°52'28"S, 72°25'53"W), located around 10 km north of the town of Hornopirén. The eruptive products of Hornopirén volcano across its three units exhibit basaltic to basaltic-andesitic compositions. The products of the most recent unit are representative of the eruptive history of the Hornopirén volcano, exhibiting fall deposits and lavas. Its mineralogy includes phenocrysts of plagioclase, olivine, spinel, clinopyroxene, and orthopyroxene. Thermometric, oxybarometric, and barometric calculations indicate temperatures of ~1090 °C, an oxygen fugacity buffer of ΔNNO+1, and the existence of two magma reservoirs beneath Hornopirén volcano at depths of approximately 7 and 23 km, respectively. Olivine phenocrysts display both normal and reverse zoning, reflecting interactions between magmas from the two reservoirs. The reverse zoning yields timescales of ~50 days, representing thermal re-equilibration recorded in crystals from the upper reservoir, while the normal zoning corresponds to magma transport from the lower to upper reservoir with timescales of ~110 days. These findings highlight the role of the Liquiñe-Ofqui Fault Zone facilitating ascent and eruption-triggering processes, with implications for volcanic hazard assessment in the region.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick… Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Magma storage timescales prior to the 1883 Krakatau eruption

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The 1883 eruption of Krakatau, located in Indonesia, is recognized as one of the most significant explosive volcanic events in recorded history, classified with a Volcanic Explosivity Index (VEI) of 6. This climactic eruption generated an estimated volume of 18 to 21 km^3 of pyroclastic density currents (PDCs), resulting in approximately 36,000 fatalities due to the associated tsunamis and ash fallout. In this work, we employed plagioclase crystals as a proxy to elucidate the long-term thermochemical evolution of the Krakatau volcanic system leading up to the eruption. The major and trace element compositions of these crystals were analyzed using Electron Probe Microanalysis (EPMA) and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), respectively. The plagioclase crystals extracted from PDC deposits exhibited a diverse compositional range, spanning from An_{38} to An_{92}. Our findings suggest that plagioclase crystals with high-An cores are subjected to prolonged storage and re-equilibration processes within more evolved melts, leading to lower magnesium content over time scales ranging from 10^3 to 10^5 years prior to their final ascent and eruption. Magma storage timescales exceed the timescales from the previous large eruptive episode (thought to be ~540s AD), so these crystals/magma batch would have ‘survived’ (stayed in the reservoir) for this large eruption. Furthermore, we compared magma ascent rates across different phases of the eruption to assess their correlation with varying eruptive styles. This comprehensive analysis contributes to a deeper understanding of the pre-eruptive conditions and dynamics that characterized the Krakatau system prior to its catastrophic eruption.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Diffusion of Sr and Ba in plagioclase: New experimental data and consequences for volcanic timescales

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Strontium and barium diffusion chronometry in plagioclase is routinely applied to mafic and felsic magmatic systems. This technique can be used to determine the timescales of magma reservoir assembly and the cooling rates of plutons and volcanic rocks, which has emerged as a useful method to assess volcanic hazards. Here we report diffusion experiments that aim to constrain the diffusivities of Sr and Ba in oligoclase and labradorite at 1 atm pressure, between 900 and 1200 °C, and as a function of the crystallographic orientation and aSiO$_2$. The experimental products were analysed by SIMS depth profiling and LA-ICP-MS line scanning. There is no resolvable dependence of Sr and Ba diffusion in plagioclase upon aSiO$_2$ or crystal orientation. However, Sr and Ba diffusivities are found to vary with the plagioclase anorthite content. The diffusion rate of Sr in plagioclase determined in this study is ~1.5-2 orders of magnitude slower than previously determined, whereas Ba diffusion is similar to previous studies. This is likely due to Ba-feldspar stability at the experimental conditions employed by previous studies, whereas Sr-feldspar was absent from their source powder assemblage. By applying the diffusivities determined in this study to plagioclase crystals from the Cerro Galán and Santorini calderas, we find timescales of ~10^5 years, with a good agreement between results from Sr and Ba diffusion modelling. Therefore, our data suggest that, at least regarding the Cerro Galán and Santorini calderas, plagioclase records the time needed to differentiate magma reservoirs and assemble large volumes of eruptible magma.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick… Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Magma Flow in Plumbing System-Type LIPs: Parameters from Anisotropy of Magnetic Susceptibility in Giant Dyke Swarms of the Equatorial Atlantic Magmatic Province

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Anisotropy of magnetic susceptibility (AMS) was applied to the Rio Ceará-Mirim Dyke Swarm, which intrudes Precambrian rocks in the northeastern corner of South America. This swarm consists of main subsets trending from NE-SW to E-W spanning over 1,000 km in length, along with minor NW-SE sub-sets. These dyke sets converge near a Cretaceous rift system formed during the fragmentation of West Gondwana. The dykes are predominantly high-TiO_2 tholeiites. Zircon U-Pb (CA-ID-TIMS) dating indicates ages ranging from 133.38 to 133.28 Ma. AMS was investigated in 110 dykes distributed along the NE-SW sub-set and integrated with previous AMS studies from the E-W sub-set. Normal magnetic fabrics (foliation subparallel to the dyke plane) show steeply plunging magnetic lineations in the dike convergence, which is interpreted as the main magmatic feeder zone. Minor feeder zones were identified locally, such as within the E-W dykes near Tertiary volcanic necks. Away from the feeder zones, the magnetic lineations typically display shallow plunges. These results were summarized into a lithospheric swelling model with a main magmatic feeder focused on the dyke swarms convergence sector. The mafic magma would have flowed laterally exploring discontinuous crustal shear-band structures that propagate outward driven by far-field pressure increases originating from the central focus.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Timescales of magmatic processes driving the 2017-2018 Manaro Voui (Ambae, Vanuatu) eruptive crisis: an olivine perspective

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In 2017-2018, after centuries of quiescence, Manaro Voui, an active volcano on the island of Ambae (Vanuatu arc), experienced a major eruption that forced the evacuation of its 11,000 inhabitants twice. This recent crisis underscores the critical gaps in our understanding of the volcano, despite the substantial hazards it presents. Our study aims to better constrain the pre-eruptive processes and their timescales. Olivine crystals within magma act as natural time capsules, recording variations in magma conditions during growth. By combining systematic crystal analysis with multi-element diffusion chronometry (Fe-Mg, Li, H), the heterogeneous composition of olivine crystals is used to identify eruption triggers and their associated timescales. Systematic chemical analysis of olivines from tephra collected from each eruptive phase enables the characterisation of magmatic environments. The dynamics of the plumbing system are assessed through Fe-Mg diffusion, revealing that the system reactivated less than ten years before the eruption, with the last injection occurring less than one month before the initial activity, marked by phreatic explosions. Li diffusion modelling confirms the timing of the final injection and highlights shorter processes such as degassing. Additionally, H diffusion profiles indicate rapid ascent rates at the eruption's onset, estimated below 6 m s^{-1}. By integrating diffusion modelling of multiple elements in olivines, we unravelled a detailed timeline of magmatic processes leading up to the eruption. This approach brings new constraints on pre-eruptive processes operating at Manaro Voui, providing a foundation for identifying precursory signals crucial for mitigating future impacts on the local population.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick… Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Understanding the crustal pathway of magmas in the Auckland Volcanic Field

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With its last eruption c. 550 years BP, the Auckland Volcanic Field (AVF), New Zealand, is still regarded as an active monogenetic field beneath a population of approximately 1.7 million people. Using the textures and mineral compositions of primarily olivine and clinopyroxene phenocrysts across 7 of the 53 volcanic centres, the aim is to provide insights into subsurface dynamics. Current theories propose magmas are not significantly affected by assimilation or extensive crystallisation, as suggested by their chemical compositions including Mg# as high as 70 - indicative of a primitive and relatively uninhibited source to surface journey for the melt. Textures such as diffuse normal and oscillatory zoning within olivine, oscillatory zoning in clinopyroxene and exsolution in oxide phases, however, indicate complexity in the crustal plumbing system which can be interpreted using mineral specific tools. Targeting Fe-Mg diffusion within tephra-derived olivine phenocrysts, the modelling software DIFFSIM is used to determine diffusion timescales as a proxy for ascent rates within AVF, with preliminary results on the scale of days to months. Input parameter constraints such as temperature and oxygen fugacity are determined in conjunction with reverse thermodynamic models produced with easyMelts software. Understanding the dynamics of the magma's ascent from source to surface, to a degree whereby a model of plumbing can be suggested, is an important component to understanding the dynamics and potential hazards of future eruptions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Reykjanes peninsula Iceland exploration, a multi-disciplinary project led by students

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The Iceland Didactical Project 2024 is an educational initiative led by second-year Bachelor students, now third-year students, in Earth and Environmental Science from the University of Geneva, supported by their professors, research group members and the SciencEscape, a non-profit science outreach organization. This project focused on developing a data-driven approach to teaching by collecting petrological, geophysical, and surface deformation data on the 2021-2024 volcanic eruptions on the Reykjanes Peninsula (Iceland). In particular, wWe collected data during a multidisciplinary field campaign, from July 21st to August 11th, 2024. In the following autumn semester, we analysed lava flow samples using optical microscopy, X-ray Fluorescence and Inductively Coupled Laser Ablation Mass Spectrometry to obtain whole rock, major, and trace element data. Additionally, we analysed minerals and matrix glasses using an Electron Probe Micro Analyzer to perform thermobarometry and chemometry. Finally, we collected diffusion profiles in olivine to retrieve information on pre-eruptive residence time for the different eruptions. We used these data in combination with structural and petrological data from the field to provide insights on the evolution of the plumbing system feeding the eruptions in the Reykjanes Peninsula, to establish eventual links between magma erupted from different localities, and to formulate hypotheses on the factors controlling temporal variations of magma chemistry observed in the samples.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Diffusion in K-feldspar: Sr, Ba, Ti and P diffusion experiments in sanidine

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Diffusion is a key to understand the timescales of magma dynamics, and thus the evolution of igneous systems. K-feldspar is a major rock-forming mineral in felsic plutonic rocks occasionally forming megacrysts, investigating the diffusion behaviour of trace elements in K-feldspar provides valuable information on magma reservoir dynamics. To provide better constraints on the timing of magmatic processes, there is a need for accurate diffusion coefficients. Therefore, we performed diffusion experiments in sanidine (Or_{98}) at 1 atm pressure, between 825 and 1050 °C, for diffusion normal to (010) at controlled $aSiO_2$, from times ranging from 1 month to 6 months. Sources of diffusant were SrO-, BaO-, TiO_2- and P_2O_5-doped cristobalite or SrO- and BaO-doped cristobalite (prepared using the sol-gel method) mixed with ground sanidine (1:1), or with ground sanidine and apatite (1:1:1). The experimental products were then analysed by SIMS depth profiling. Sr diffusion rate is ~2 orders of magnitude slower than previously determined, while Ba, Ti and P did not show any measurable diffusion profiles, indicating that Ba and Ti likely diffuse more slowly than previously determined. Zoning in Ba in natural K-feldspar megacrysts thus predominantly records crystal growth processes that are weakly affected by diffusion. To further investigate Ba diffusion, we annealed a natural sanidine megacryst with complex Ba zonation (Taápacá, Chile, Rout et al. 2020) at 925 °C for 3 months at controlled $aSiO_2$.Ba profile (before and after annealing) were measured with EPMA and LA-ICP-MS to potentially retrieve diffusion coefficient for Ba.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Trace element diffusion in tephrite-phonolite couple experiments as a function of temperature, H2O contents and oxygen fugacity

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Trace element diffusion in magmas is of major importance, as trace elements are used as proxies for a large variety of igneous processes (magma recharge, crystal growth/dissolution or volatile exsolution) and their associated timescales. The database of diffusion coefficients (D) has increased significantly in the last decades, but gaps still exist for water-rich melts. Moreover, although alkaline melts constitute a significant volume of ocean island magmatism, such liquids are generally under-represented in the current trace element diffusion database. Therefore, a series of interdiffusion experiments between tephritic and phonolitic melts from the Canary Islands were run in internally heated pressure vessels at variable conditions (300 MPa, 1150-1300°C, 0.3-3.3 wt.% H_2O). Concentrations of 13 trace elements (V, Zr, Nb, Co, Ta, Hf, U, Th, Sn, Sr, Ba, Rb and Cs) were determined by LA-ICP-MS and effective binary diffusion coefficients (D) were obtained by a modified Boltzmann-Matano analysis. Preliminary results show a systematic relationship between trace element diffusion and ionic radius (r) in all runs, with a maximum in diffusivity at r ~ 1 Å (Sn, Sr, Ba). As already observed for major elements [1], log D of trace elements show a non-linear relationship with melt H_2O contents with a convergence of D towards the water-rich end at different temperatures. This dataset will allow constraining magma interactions and dynamics in bimodal eruptions, in Tenerife and other islands, where banded pumices resulting from mixing between basanite/tephrite and phonolite are common. [1] González-García, D. *et al.* (2024). Eur. J. Mineral. 36(4), 623–640. doi: 10.5194/ejm-36-623-2024

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Rapid differentiation, gas accumulation and the size of magma chamber beneath Hekla volcano, Iceland, from 238U-series disequilibria.

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Eruptions at the constantly inflating Hekla volcano in Iceland start explosively and ends with an emission of a basaltic andesite lava of uniform composition. Measured Ra-Th radioactive disequilibrium decreases from 14% excess of ^{226}Ra over ^{230}Th to 5% with magma differentiation. This decrease is controlled by plagioclase fractionation alone. Therefore, the magma differentiation time from basalt to intermediate magma beneath Mt. Hekla can be shown to be significantly shorter than three centuries. From the estimated magma production rate, the volume of the basaltic andesite magma accumulation zone/reservoir/magma chamber are less than 2 km^3. Gas accumulate in a hermetic magma chamber can lead to an overpressure and an eruption. It is hard to detect but the decay of ^{226}Ra produces ^{222}Rn that will be stored together with the available major gas species, and rapidly decay to ^{210}Pb. Such radon accumulation thus will lead to excess ^{210}Pb over the grandparent ^{226}Ra in the magma accumulating the gas phase. Eruptions at Hekla volcano start explosively producing tephra before an effusive lava forming phase. The tephra of the five latest eruptions of Hekla (1947 to 2000) has either excess of ^{210}Pb over ^{226}Ra or are in radioactive equilibrium, as are all the lava flows. Since 1947 CE the volume of erupted tephra decline regularly, a trend that correlates with a reduction in radon flux from a deep-seated basalt source into the basaltic andesite magma chamber beneath Hekla. A renewal of the basalt source seems to be needed for the next eruption at Hekla volcano.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Magma storage, pre-eruptive dynamics and timescales of the 1956 eruption of Bezymianny volcano (Kamchatka)

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Laterally directed blasts are explosive events following a major sector collapse of a volcano, with the potential for devastating areas of several hundred km^2, due to powerful dilute and turbulent pyroclastic density currents. The catastrophic flank collapse on 30 March 1956 of Bezymianny (Kamchatka, Russia) was the climactic phase of the first historical magmatic eruption of this volcano, after 1000 years of dormancy. Magma stored in a cryptodome was depressurized by a sector collapse, generating a laterally directed blast immediately followed by pumiceous concentrated pyroclastic density currents. We infer the storage conditions of magma using sample vesicularity, amphibole destabilization rims, volatile contents in melt inclusions, microlite textures, and phase compositions. We propose a three-level magma storage characterized by a deep reservoir (> 200-350 MPa, ≥ 840 °C), a shallow reservoir (50-100 MPa, 850-900 °C) in which the pre-cryptodome magma resided and from which the post-blast pumiceous magma originated, and a subsurface cryptodome (< 25 MPa, ~900 °C) from which the blast was initiated. By combining petrological and temporal constraints from orthopyroxene, magnetite, and amphibole chronometers, we track magmatic processes over twelve years prior to the eruption, followed by magma ascent to a shallow reservoir and a heating process at least three months before the eruption. Magma was last stored in a cryptodome at least two months before the climactic phase of the eruption. Reconstructing magma dynamics on a timescale of months to years before major flank collapses and laterally directed blasts thus provides valuable information for volcanic risk mitigation.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick… Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Influence of Deformation on Crystallization: Experimental Insights on Magma Conduit Dynamics

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Crystallization processes in trans-crustal magmatic systems play a critical role in shaping magma rheology, conduit dynamics, and eruptive behavior. The presence of a deformation field within plumbing systems can significantly impact crystal nucleation and growth. This study makes use of novel crystallization experiments to quantify the impact of deformation on nucleation, crystallization, mineral phase proportions, and residual melt composition. The experiments were performed on natural trachybasalts from Mt. Etna, under controlled pressure and temperature conditions at the University of Perugia. Mineral zoning was forced by oscillating the temperature (1170 - 1130 °C) while a strain rate gradient was imposed with a concentric cylinder apparatus with the spindle rotating at constant strain rate. Mineral and glass chemical variations were analyzed using an electron probe microanalyzer (EPMA) at the University of Geneva. The data were analysed using custom-built unsupervised and supervised machine learning algorithms (e.g., Hierarchical Clustering and Random Forest). The effect of deformation on nucleation, growth, and mineral phase proportions was quantified using backscattered electron diffraction (EBSD) at the University of Vienna. Results show that deformation enhances nucleation rates, increases crystal number density, and alters mineral phase proportions and thus the composition of the residual melt. These findings highlight the need to consider deformation processes when interpreting the textural and chemical variability of volcanic products. Finally, we explore the potential links between our experimental results and the chemical evolution of magma at Mt. Etna during the 2021 eruptive sequence at the South-East summit crater, suggesting possible implications for conduit dynamics.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.2: Tick, tick... Boom! Timescales and dynamics of volcanic plumbing systems revealed by multidisciplinary approaches

Allocated presentation: Poster

Field-based measurement of xenolith size, shape, and number density in volcanic deposits: Example from Lanzarote (Canary Islands) and implications for magma ascent

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Mantle xenoliths constrain the ascent rates of their carrier magmas, as magmas must ascend faster than xenoliths sink. While Stokes Law dictates that xenolith size controls settling velocity, quantitative data on xenolith sizes in volcanic deposits are scarce. Here, we present field-based measurements of xenolith size, shape, and number density from the five-phase 1730–1736 CE Timanfaya eruption and the smaller 1824 eruption on Lanzarote to assess magma ascent conditions and eruption styles over time. On outcrops, xenolith sizes (equivalent circle radius up to 7.5 cm) and number densities (up to ~20 xenoliths m^{-2}) were highest during Phase 1 of the eruption, decreased in subsequent phases, and increased in the final episode. The largest xenoliths, with equivalent circle radius of 9.0 cm, are found as bombs at the Phase 1 Pico Partido cinder cone. Xenoliths show mean aspect ratios (long/short axes) of 1.4–1.9. The 1824 Volcán Nuevo del Fuego eruption also produced large xenoliths, but pahoehoe flow cross-sections reveal xenoliths are heterogeneously distributed within specific flow lobes over time. Despite similar maximum xenolith sizes and inferred magma ascent rates (~0.1–0.2 m/s), Pico Partido exhibited explosive activity, while Volcán Nuevo del Fuego was dominantly effusive, highlighting an interesting case of decoupling between ascent rate and eruptive style. Our dataset of >960 xenoliths provides testable constraints for independent estimates of magma ascent rate at Timanfaya and general ascent models for mantle xenolith-bearing magmas.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Talk [Invited]

Unraveling timescales of magmatic processes through diffusion modeling: Insights from diverse volcanic contexts

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Diffusion modeling in zoned crystals provides a powerful tool for quantifying the timing of magmatic processes across diverse volcanic systems. By focusing on olivine, we explore a variety of processes constrained through crystal zoning patterns, including dike propagation dynamics, magma mixing, magma storage, and mush generation. These insights are critical for understanding volcanic unrest and eruption forecasting. The versatility of diffusion chronology is illustrated by three representative cases. At Paricutin (Mexico), olivine zoning in the early tephra captures the thermochemical gradients and timescales associated with dike propagation, shedding light on the dynamic conditions at the dike tip during the initial stages of magma ascent and the transition to steady magma flow. At Piton de la Fournaise (La Réunion), olivine and melt inclusions record the temporal coupling between shallow magma storage, the generation of a crystal mush, and lateral magma transport, offering insights into the processes leading up to the caldera collapse in 2007. Finally, in the Canary Islands, olivine crystals from monogenetic eruptions reveal several pre-eruptive mixing events, enabling correlations with seismic unrest data. Moreover, comparing timescales derived from multiple eruptions has allowed us to propose a general model, wherein early intrusions create thermal pathways that facilitate later eruptions. This framework integrates geochemical, petrological, and unrest data to identify recurring timescales of unrest on the order of years, months, and days preceding monogenetic eruptions. This work has been partially financed by the grant PID2023-151693NA-I00 funded by MCIN/AEI/10.13039/501100011033.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Talk [Invited]

Bayesian approaches to inferring dates and rates of magmatic processes

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A fundamental problem in geochronology, particularly including that of magmatic and volcanic processes, is that the events which can be directly dated by geochronology (e.g., mineral crystallization or closure) often do not directly correspond to the events and processes of geologic interest (e.g., eruption or emplacement). While this problem may be approached statistically from either a Bayesian or Frequentist perspective in equally valid ways, the ease of integrating other prior information (either empirical, or from physics-based forward modeling) in Bayesian estimates has recently proven attractive in some cases. Here we will consider recent developments and future opportunities for such Bayesian approaches to addressing the gap between directly datable events and those which can be only indirectly constrained, and the implications thereof for better constraining the dates and rates of magmatic and volcanic processes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Talk

New Cosmogenic Exposure Dating of Fissural Volcanic Episodes in Afar: Implications for Magmatic Processes and Plumbing System Organisation

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Divergent plate boundaries offer prime sites to study crustal extension and volcanic processes. The Afar depression, where active continental break-up and the transition from continental to oceanic rifting, provides a unique natural laboratory for these investigations. The magmatic segments within Afar (Erta Ale, Dabbahu-Manda Hararo and Asal) share structural organisation analogies to those in mid-ocean ridges. These segments offers insights into the mantle and crustal processes that control magma transfer, storage, and eruption. This study focuses on the dynamics of magma transfer through the crust, the organization of the plumbing system, and the processes controlling these mechanisms. We combine high-resolution multispectral orthoimages and digital elevation model, precise geological mapping, field investigations, cosmogenic ^{36}Cl exposure dating, and lava geochemistry to constrain the timing and evolution of magmatic events. Due to the systematic axial resurfacing along the segments, only the very last volcano-tectonic cycles are preserved and documented with exposure ages. Our results document the last rifting episodes for each segment: Gumat Mali-Manda Hararo (~ 0.5 to 35 ka), and Asal (~1 to 8 ka). The recent exposure ages reveal periodic recharge of shallow magma reservoirs that ultimately feed lateral dyke injections and surface eruptions. Our findings reveal the dynamic magma storage and transfer within the Afar axial rift, where segments are at different rifting stages. Variations in reservoir recharge and differentiation highlight distinct storage zones and potential connections between subsegments. These insights show how periodic magma transfer and differentiation cycles shape the rift magmatic evolution, with important implications for local hazards.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Talk

Prolonged post-emplacement cooling of andesitic-dacitic lava flows produces optimal groundmass material for Ar/Ar dating

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$^{40}Ar/^{39}Ar$ ages for lava flows contribute greatly to organizing the geological maps, eruptive histories, and petrogenetic trends that underpin hazard assessments at active volcanoes. These age data are collected by analyzing the groundmass material of rock samples; therefore, it is important to understand how the cooling and crystallization of melt affects the distribution of K and Ar in lavas during their effusion and emplacement. We have undertaken a petrological and geochemical study of late Pleistocene to Holocene andesitic-dacitic lavas from Ruapehu volcano, Aotearoa New Zealand, for which $^{40}Ar/^{39}Ar$ ages were previously determined. Studied samples from the exposed interiors of lava flows yielded ages with relative 2σ precisions of 2–32% (e.g., 42.8 ± 1.0 ka; 8.8 ± 2.8 ka). Groundmass microlite phases in these lavas are plagioclase, orthopyroxene, and magnetite. New microanalytical data show that pre-existing melt was quenched to form rhyolitic glass at lava margins; however, melt fractionation during slow cooling in lava interiors formed subhedral sanidine (~11 wt.% K_2O) and patchy tridymite. The contribution of sanidine to the K/Ca budget of samples peaked through the middle stages of step-heating experiments, which resulted in consistent gas release spectra and measurement of high-precision plateau ages. Crystallization of sanidine in many Ruapehu lavas was aided by their impoundment by valley-filling glaciers during the last glacial period, which formed abnormally thick units (>30 m) with interiors that underwent prolonged cooling behind quenched margins. Eruption ages for these lavas have aided reconstructions of the edifice growth history, paleo-glacier extents, and geomagnetic excursion dynamics.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Talk

Crystal-mush remobilization timescales in the Snæfellsnes volcanic zone (W-Iceland): Insights from olivine Fe-Mg diffusion chronometry

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Efforts to understand pre-eruptive magma storage and transfer in Iceland's neovolcanic zones have largely focused on on-rift systems, leaving off-rift volcanic flank zones like the Snæfellsnes Volcanic Zone (SNVZ) poorly constrained. Elevated seismicity detected in the Grjótárvatn area of the Ljósufjöll volcanic system (SNVZ), starting in 2021, has intensified since August 2024, including the largest earthquake on 18 December 2024 (M 3.1) and short tremor bursts since 2 January 2025 (https://en.vedur.is/about-imo/news/seismic-activity-in-grjotarvatn-has-increased-in-the-last-months). This has fuelled speculation about a potential reawakening of SNVZ eruptive activity, akin to the Reykjanes Peninsula in 2021. We present a combined quantitative petrological approach combining clinopyroxene-melt, clinopyroxene-only, and Raman-based fluid inclusion barometry with olivine Fe-Mg diffusion chronometry to constrain magma storage depths and timescales associated with magma mobilization and transfer leading up to the Holocene Búðahraun (~5.0-8.0 ka) and Berserkjahraun eruptions (~4.0 ka) in the SNVZ. Olivine diffusion timescales from Búðahraun lava and Berserkjahraun lava and scoria samples indicate timescales ranging from 6 days to approximately 4.1 years, with median pre-eruptive magma mobilization timescales of 34 to 36 days. Notably, 81% (n=111) of the timescales are shorter than 3 months (~93 days). Olivine-hosted fluid inclusions (n=109) record entrapment pressures of 2.5 – 4.5 kbar, with medians of 3.6 (Búðahraun) and 3.7 kbar (Berserkjahraun). Clinopyroxene-based barometry returns lower median pressures of 2.7 and 2.5 kbar, respectively. Given the sparse petrological documentation and monitoring infrastructure in the SNVZ, our integrated dataset will provide critical insights into magma storage and mobilization dynamics in this underexplored volcanic region.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Talk

U-Th ages and compositions of zircons in Dominica: constraints on a magma plumbing system

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Within the last 200 kyr, Dominica has experienced multiple voluminous eruptions across the island and continues to show signs of potential future activity, with active hydrothermal areas, including Boiling Lake, and periodic swarms of shallow earthquakes. Like other Caribbean islands, it has been proposed that Dominica has a trans-crustal magmatic system, deeply sourced and wet, leading to multiple explosive eruptions, preserved as ignimbrites within valleys and coastal exposures. In this study, we present >200 U-Th ages and compositions of zircon rims, which help to refine the eruption age(s), crystallization histories, and sources of six ignimbrites from across the island. Several of the ignimbrites display polymodal distributions of ages, including eruption age zircons (relative to minimum ^{14}C ages and (U-Th)/He eruption ages from previous studies). There is no discernible island-wide time progression of eruptions geographically, as previously proposed. Many of the units have significant antecrystic zircon population(s), punctuated by hiatuses of 10s of kyrs, suggesting sub-solidus storage conditions and intermittent crystallization prior to eruption. Overall, trace element concentrations in the analyzed zircons span broad ranges, with little correlation with respect to ignimbrite and/or zircon age. Uranium concentrations are low, with an average of 135 ppm, whereas Hf spans an extremely broad range from ~2200 to ~18,000 ppm. The distinct zircon crystallization histories from each ignimbrite deposit, coupled with the heterogeneous zircon compositions suggests that each explosive unit has a unique ascent path, and that ascending magma may entrain multiple discrete pockets of previously crystallized material en route to the surface.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Talk

What do zircon age distributions tell us about the magma storage conditions of large ignimbrite eruptions?

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In the last decade, high precision U-Pb zircon geochronology studies have been conducted on numerous large-volume felsic eruptions. Many of these studies have yielded single zircon ages with <10 kyrs uncertainties. This unprecedented resolution has allowed investigation of pre-eruption storage timescales, but the interpretation of these datasets remains contentious due to the potential for whole grain dissolution to average multiple zircon age domains. This averaging has the potential to either decrease age dispersion within a zircon population by averaging multiple autocrystic growth domains, or to increase age dispersion within a zircon population by integrating inherited or antecrystic zircon cores. To provide new insights into this issue, we compiled CA-ID-TIMS zircon U-Pb datasets combined with petrographic and geochemical data for 31 ignimbrites. These data reveal that the age dispersion in crystal-poor ignimbrite is unresolvable or <100 kyrs, while crystal-rich systems frequently record age dispersion >200 kyrs. These relationships suggest that the high-precision datasets faithfully document zircon crystallization timescales. Further, we evaluate two mechanisms to produce short duration zircon crystallization intervals in crystal-poor systems: 1) late zircon saturation immediately preceding eruption; or 2) extraction of a zircon-saturated melt from a crystal mush immediately preceding eruption without remobilizing existing zircon. While the first mechanism may be possible in exceptional scenarios, it requires generation of a parental magma by re-melting of zircon-free cumulates. If the second mechanism is instead the dominant process for creating these systems, it places strong constraints on the maximum melt velocities possible during melt extraction from the crystalline mush.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Crystal size distribution (CSD) in a lava sample from Ruapehu volcano, New Zealand: a case study comparing the use of semi-automatic tools in 2D versus 3D images.

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The determination of crystal size distributions (CSD) is used for the determination of the magma residence times, using a well know crystal growth rate and the slope of the distribution. Furthermore, once the residence times are obtained these can be used together with the depth to calculate the ascent rates. Usually, the CSDs are determined using two-dimensional (2D) images in which crystals can be overlapped misrepresenting the natural tridimensionality of the particles. The use of three-dimensional (3D) images where crystals can be measured directly, is key in providing a more robust distribution, particularly for samples with a high density in crystals. For these samples the use of semi-automated tools facilitates the crystal outlining and measurement processes. We evaluated the comparability between 2D and 3D CSD plots, assessing the similarities and differences for different mineral shapes and axis plots in magnetite and pyroxene, obtained using semi-automatic tools in one lava sample from Mangawhero Formation. The sample was analyzed through back-scattered scanning electron microscopy (BS-SEM) and synchrotron radiation X-ray micro-computational tomography (SR-XCT). Our findings include similar patterns for 2D and 3D CSDs for all axes, including similar kinked features; closer results between 2D and 3D CSDs for non-equant tabular shapes, and a lesser influence of the aspect ratios over the 2D intermediate axis plots. Additionally, a better comparability in terms of shapes and slopes was observed between large axis plots irrespective of the crystal shapes and number of crystals.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Constraining ascent velocities of the world's youngest kimberlite magmas using diffusion chronometry modelling

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Kimberlites are enigmatic igneous rocks which transport diamonds to Earth's surface. Despite their importance, many aspects of kimberlite volcanism remain unknown. This project aims to constrain ascent velocities of kimberlite magmas using diffusion chronometry. We analyze lavas from the youngest known kimberlites, the Igwisi Hills Volcanoes. Microanalytical work has revealed 3 olivine populations in the lavas. Olivine-I are ellipsoidal, > 1000 μm and have a Mg-rich core derived from mantle peridotite. Olivine-IIa crystals are subhedral-euhedral, < 1000 μm, and also have an Mg-rich peridotite core. Olivine-IIb crystals have a similar size and morphology to olivine-IIa crystals but possess an Fe-rich core, likely to be derived from sheared peridotite. Crystals from all populations also feature four magmatic zones (internal zones, rims, rinds & outermost rinds). Al-in-olivine thermo-barometry reveals a range of core equilibration temperatures from 734-1181°C and pressures from 25.9-49 kbar. Magmatic zones have equilibration temperatures ranging from 818-912°C as revealed by olivine-spinel pairs thermometry. EBSD has been carried out on olivine crystals to determine orientations of geochemical transects. These data are being used to conduct diffusion chronometry modelling using a range of models from excel based analytical solutions to the sophisticated DFENS (Diffusion Using Finite Elements and Nested Sampling) numerical model ran in Python. Preliminary results from analytical models suggest diffusion from cores to internal zones is very slow (average 484 years) and represents storage rather than ascent. We predict timescales calculated between magmatic zones will be significantly faster and reflect the rapid ascent kimberlites are known to undergo.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Rapid assembly of a super-sized magma body over a millennial timescale

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The accumulation and pre-eruptive storage of large silicic magma bodies in the upper crust are pivotal not only for understanding igneous petrology and volcanology but also for volcanic hazard mitigation. Yet, the elusive nature of timescales associated with these magmatic processes continues to challenge researchers. Currently, zircon dating and diffusion geochronometry offer conflicting estimates: zircon dating implies prolonged upper crustal magma residence times (10^4-10^6 years), while diffusion geochronometry consistently points to much shorter timescales (10^1-10^3 years). Both methods rely on mineral grains from silicic plutonic and volcanic rocks, which may record intricate thermal histories that complicate the direct dating of magma accumulation. Here, we introduce a novel approach that synergizes volcanic glass geochemistry, eruption magnitude, and tephrochronology to elucidate the processes of magma accumulation leading to a catastrophic caldera-forming eruption. By meticulously integrating proximal and distal tephra records, we show that a super-sized magma body (100s of km^3) can form within a millennial timescale. Moreover, employing the cryptotephra extraction technique, we uncover previously overlooked ash records that signify rapid remobilization events of the shallow magma reservoir following caldera collapse. These findings support the concept that large melt-dominant bodies within the upper crust are short-lived structures, which are rapidly assembled from deep source reservoirs and erupt on short timescales.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Sequential triggers of Plinian eruptions at Sakurajima Volcano inferred from multi-diffusion analyses

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Understanding the triggering mechanisms of Plinian eruptions remains an important scientific challenge. Mafic magma recharge and subsequent mixing are often considered direct triggers of eruptions. However, despite the geodetic detection of frequent recharge in active volcanoes, such processes rarely result in Plinian eruptions, making their roles as triggers ambiguous. To enhance our understanding of these mechanisms, we conducted diffusion modeling on multiple mineral phases and investigated the magmatic processes leading to historical Plinian eruptions at Sakurajima Volcano, Japan, over various timescales. The reverse zoning of orthopyroxene phenocrysts commonly indicates diffusion timescales of years or more following recharge-and-mixing, which may represent the ultimate triggers of the eruptions (cf. Putirka, 2017). By contrast, almost all magnetite phenocrysts, where elemental diffusion is much faster, lack zoning. Given that the mixed magmas after recharge were stored in a shallow, thick conduit before the eruptions (conduit pre-charge; Araya et al., 2019), the pre-charged magma body had been reposed for longer than the diffusive re-equilibration time of magnetite (several tens of days). This shallow stagnation may be related to precursory phenomena, as early as six months before the latest AD 1914 eruption. The timescales of magma ascent to the surface after this stagnation period are up to tens of hours, as inferred from the zoned magnetites which occurred rarely. Crystallization-driven vesiculation during the pre-charge, which can produce sufficient overpressure to cause an eruption, could act as the immediate trigger (cf. Putirka, 2017). The Sakurajima case demonstrates the hierarchical timescales of trigger processes

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Mush disaggregation and dike propagation timescales at active volcanoes – Evidence from the 2022-2023 Fagradalsfjall eruptions

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The 2021-2023 Fagradalsfjall eruptions provide a unique perspective on the initial stages and temporal evolution of a basaltic magma plumbing system, since its previous eruptions occurred 7,000 years ago. In this work, we focus on the 2022 and 2023 Fagradalsfjall eruptions, integrating our petrological and geochemical dataset with data from the 2021 Fagradalsfjall eruption. We show that the 2022 and 2023 Fagradalsfjall eruptions were sourced from a near-Moho magma domain at ~14 km depth, similar to the 2021 Fagradalsfjall eruption. However, clinopyroxene-melt barometry suggests that the 2022 and 2023 magmas experienced crystallization either in an embryonic mid-crustal reservoir or during slow ascent within the magma conduit. Olivine and plagioclase crystals constitute two different populations in the crystal cargo, with their diffusion timescales representing two different processes. Plagioclase diffusion timescales reveal the erosion of crystal mushes, a process that unfolded over the months and days prior to the 2022 and 2023 eruptions. The progressive shortening of these timescales from 2021 to 2023 suggests an increasingly rapid response of the magmatic system to deep melt injections. In contrast, olivine diffusion timescales capture the timing and duration of dike opening and propagation from near-Moho depths, as evidenced by the strong correlation between their cumulative frequency distribution and pre-seismic activity. Combined geophysical, petrological, and barometric data suggest that the 2022–2023 propagating dikes took considerably more time to traverse the lower crust and reach mid-crustal levels than the upper crust which was breached within a few days through a fully established magma pathway.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Entire magmatic evolution of the Kikai caldera revealed by zircon triple (U-Pb, Th-Pb, U-Th) dating and its chemistry

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Elucidating the volcanic history of the Kikai caldera, an active large volcano that erupted a volume of ~160 km^3 at 7.3 ka off the southern coast of Kyushu Island, southwest Japan, is critically important to assess future volcanic hazards on a regional and/or global scale. Nevertheless, revealing its volcanic history before the 7.3 ka eruption has been challenging partly because it is a mostly submerged caldera. Here, we show that the Kikai caldera experienced a geochemically unique silicic lava eruption at ~250 ka by using zircon triple (U-Pb, Th-Pb, U-Th) dating and its chemistry. The 7.3 ka eruption contained 1.5–1.0 Ma zircons, indicating that zircon crystallizing magmatism initiated at this time at the Kikai caldera. We further infer that enigmatic large eruptions at 0.7–0.6 Ma are reasonable and therefore the Kikai caldera may have experienced at least 5 large eruptions during its 1.5–1.0-million-year magmatic history.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Magma ascent within days confirmed by systematic diffusion modelling on xenocrystic olivine across the Auckland volcanic field, New Zealand

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We selected seven basaltic volcanoes across the Auckland volcanic field (AVF) for a systematic evaluation of timescales of magma storage and ascent using diffusion modelling of major and trace elements and water within xenocrystic olivine of mantle origin. A total of 73 high-resolution profiles were measured on 71 olivine xenocrysts by electron microprobe. Profile components from a crystal interior to edge, include (1) a xenocrystic flat plateau with constant Fo# [100 × molar Mg/(Mg + Fe)] between 90 and 94, (2) a first magmatic overgrowth with Fo#80–83, and occasionally (3) a second reverse magmatic overgrowth with higher Fo# compared to the first overgrowth, reflecting recharge of more mafic magma. The boundaries between these components have smoothed transitional/diffusive Fo# areas. The very outer edge of the crystals is commonly characterised by a final thin (<10 μm) diffusive rim with a rapid decrease in Fo# (<80). The results show that total diffusion timescales within days are common to all examined volcanoes across AVF. Water profiles measured by FTIR show diffusion timescales within hours, representing rapid magma ascent after water-degassing starts at a few km depth. Our results reconfirm the conclusion of complex magma storage and fast magma ascent from a published study on the Pupuke maar alone, but also suggest shorter rise times from magma source regions, (with a mode at 2 days and 80% of examples <16 days) as well as complex conditions within deep magma storage over various timescales beneath the AVF.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Cooling rates and crystal residence times in plutonic rocks determined by diffusion chronometry (Adamello batholith, Italy)

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Constraining the temperature evolution of felsic magma reservoirs through time constitutes an important scientific and societal challenge in order to mitigate future volcanic hazards. Diffusion chronometry emerged as a valuable tool to track the timescales of magmatic processes and is now routinely applied on erupted volcanic products to infer crystal residence times and mixing-to-eruption timescales. Despite some attempts to apply diffusion chronometry to plutonic rocks, their slow cooling prevented a robust interpretation of the retrieved timescales. Here we investigate the cooling rates and crystal-melt segregation timescales in the Western Adamello (WA), Italy. It is mainly composed of tonalite and volumetrically minor cumulative gabbro and leucotonalite having strongly zoned plagioclase crystals, and segregated granite. After determining the crystallisation temperature of plagioclase and the initial conditions prior to diffusion, cooling rates were inferred based on plagioclase mantle-to-rim profiles and correspond, within uncertainty, to cooling rates calculated using thermal modelling and obtained by previous studies using $^{39}Ar/^{40}Ar$ dating. Crystal-melt segregation timescales were then calculated based on the diffusion modelling of plagioclase core-to-mantle profiles and the retrieved cooling rates. The calculated timescales (~10^4-10^5 yr) likely correspond to the plagioclase core-to-mantle residence time before crystallisation of the rim. Interestingly, these crystal residence times are similar to the zircon crystallisation timespan recorded in the WA, and to the crystal residence times obtained on historical volcanic eruptions. Overall, these findings highlight that plutonic systems can be used to reconstruct magmatic timescales and support the hypothesis of a close connection between plutonism and volcanism.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Evolution of Plio-Pleistocene shallow-level granites and associated rhyolites in the Tuscan Magmatic Province (Italy).

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Understanding the connection between granitic plutons and silicic volcanic rocks is crucial to shed light on the processes triggering volcanic eruptions. A critical limitation to progress in this quest is the overall scarcity of well-preserved plutonic-volcanic pairs. Peraluminous cordierite-bearing granites and rhyolites, representing pure crustal anatectic magmas, occur in the Tuscan Magmatic Province (Italy). High precision U-Pb dating of magmatic zircon crystals from the Larderello-Travale granites yielded ages ranging from 4.5 to 1.6 Ma, suggesting four pulses of magmatic activity. One of these pulses has zircon with ages spreading ca. 400 kyr, from 2.6 to 3.0 Ma. These ages are identical to those determined from zircon in rhyolitic lava flows and domes (Roccastrada rhyolites) cropping out 10 km to the south of the intrusions. Granites and rhyolites have similar whole rock major, trace element and isotope compositions. Individual samples are characterized by a significant variability in zircon oxygen isotope composition and by a large spread in plagioclase $^{87}Sr/^{86}Sr$ ($\Delta^{87}Sr/^{86}Sr > 1*10^{-3}$), with several crystals exhibiting intra-grain isotope variability. Some of the plagioclases in the granites have cores with high anorthite contents (80 mol%), displaying crustal Sr isotope signatures (> 0.7145). Mineral-scale isotope data support the involvement of multiple crustal sources in the genesis of granites and rhyolites. The large age span recorded by the zircon suggest that crystallization started in the middle crust in isotopically-diverse magma batches that were successively assembled into shallow-level intrusions or erupted. These granites and rhyolites represent different outcomes stemming from a composite long-lasting magma reservoir.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Reconstructing the geological record of caldera-forming eruptions on Sumatra (Indonesia)

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The island of Sumatra (Indonesia) has been the site of numerous caldera-forming eruptions that spread voluminous silicic tuffs throughout the region. Among these large eruptions, only the Toba tuffs have been studied in great detail, while others have so far received less attention. With this study, we contribute to bridging this knowledge gap by characterizing the mineralogy, geochemistry, crystallinity and age of the proximal deposits of large ignimbrites from north to south Sumatra. Our research shows that between ~7.3 Ma and ~33 ka the region experienced multiple cataclysmic eruptions that culminated with caldera collapses. The bulk-rock compositions of the pyroclastic deposits associated with these eruptions define a calc-alkaline suite ranging from andesites to high-SiO_2 rhyolites. However, the matrix glass compositions of all the ignimbrites are rhyolitic, indicating that crystallinities and mineral assemblages primarily control the bulk-rock geochemistry. The geochemical signatures (particularly K_2O, CaO and trace element contents), mineral assemblages (e.g, presence or absence of K-feldspars, biotite, amphibole and quartz in addition to plagioclase, pyroxenes and oxides) and mineral chemistry allow fingerprinting of the different sources. The knowledge obtained from the study of these large ignimbrites is essential to re-evaluate the frequency of caldera-forming eruptions on Sumatra and the geochemical variations of erupted magmas in the north-western sector of the Sunda volcanic arc. Furthermore, since most of the information about the volcanic activity in Indonesia comes from marine tephra layers with unknown sources, this research contributes a foundation for building a database useful to tephrostratigraphic correlations in south-east Asia.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Magmatic duration & mantle flux as drivers of magmatic processes?

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Today, a majority of our frontier research questions focus on magmatic processes, including their timing, duration, and trans-crustal nature. Yet, traditional methods for classifying volcanic systems rely mainly on characterizations of shallow, syn-eruptive processes. To address this mismatch, I use a new graphical method, known as “magmatic trees,” to compare volcanoes based on their trans-crustal magmatic processes. Applying this method to the modern US Cascades arc, patterns of magmatic processes emerge. For example, both Mt. Hood and Mt. Rainier tend to repeatedly produce andesite through the same set of trans-crustal processes with eruptions initiated over timescales of days to months. In contrast, neighboring Mt. St. Helens erupts a wider range of compositions produced by a greater diversity of trans-crustal processes with eruptions initiated over a wider range of timescales. Comparing the magmatic trees for Cascades’ volcanoes to geochronologic and volumetric data, I hypothesize two key variables dictate the trans-crustal magmatic processes at a given volcano within a given tectonic setting: 1) the duration of volcanism and 2) the volumetric flux of magma from the mantle to the crust. In this context, older volcanoes that experience lower mantle fluxes tend to exhibit a repeated set of magmatic processes, whereas younger, higher flux volcanoes reveal more variable magmatic processes. If true, this hypothesis provides a framework to elucidate not only the “why?” of magmatic processes, but to understand what may drive the relative diversity and timescales of processes at a given volcano.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Assigning an eruption age: The challenges of dispersed single crystal Ar-Ar ages and insights from geochemistry

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The increasing precision of modern noble gas mass spectrometers has revealed significant dispersion in datasets of single crystal $^{40}Ar/^{39}Ar$ eruption ages, ranging from tens to hundreds of thousands of years. This widespread observation suggests that the dispersion is unlikely to be an analytical artefact but instead results, at least in part, from geological or volcanological processes. The geochronology and volcanology community faces two main challenges in light of these observations: 1) interpreting such dispersed datasets to assign a meaningful 'eruption' age, and 2) understanding the magma storage and/or eruption mechanisms that allow such a wide range of single-crystal ages to be preserved. We present data from four silicic volcanic eruptions in the Turkana Basin, within the Kenyan branch of the East African Rift System: the Silbo (~750 ka), Nariokotome (~1.26 Ma), and Koobi Fora (~1.5 Ma) tuffs from the Plio-Pleistocene, and the Miocene Buluk Tuff (~16 Ma). In these cases, single sanidine crystal $^{40}Ar/^{39}Ar$ apparent ages span 80,000 to 300,000 years for a single eruption. Notably, this age variance persists both within and between individual pumice clasts of a given eruptive sequence. In this study, we combine major and trace element geochemical analyses with radiogenic isotope (Sr-Nd-Hf-Pb) geochemistry to investigate the possible magmatic controls on the observed age variations. Additionally, these are the first radiogenic isotope geochemistry data for the extensive Plio-Pleistocene silicic volcanic deposits in the Turkana Basin and reveal important genetic affinities to other volcanic activity in the rift system.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Geological constraints on the crystallization timescales of high-silica magmas and the diffusivity of Ti in quartz in the Searchlight Magmatic System (NV, USA)

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High-silica magmas (≥68 wt. % SiO_2) source some of the most impactful volcanic eruptions on Earth. Crystallization timescales estimated for these magmas vary widely (10^1-10^6 a), with a particularly large gap between results from zircon geochronology and quartz geospeedometry. However, recent work re-examining the diffusivity of Ti in quartz has introduced new uncertainty into our understanding of this parameter and results from Ti-in-quartz geospeedometry. Here, we utilize constraints from field relations, geochronology, geobarometry, geochemistry, heat loss models, and crystal growth rates to establish limits on the crystallization timescales of high-silica magmas in a natural system. We use these limits to critically assess the Ti-in-quartz diffusivity in this system. The Searchlight Magmatic System (NV, USA) includes the tectonically tilted Searchlight pluton and coeval Highland Range volcanics. Prior work suggests high-silica magmas (rhyolite, leucogranite) in this system represent melts extracted from the pluton. Results from Ti-in-quartz diffusion chronometry of a rhyolite unit range from 10^2-10^8 a, depending on the diffusion law applied. Results using the two slowest diffusivities exceed timescales suggested by zircon geochronology of the plutonic source (100-200 ka), plagioclase sizes (10^0-<10^3 a), and heat loss models (10^1-10^3 a). Quartz growth rates estimated using the Ti-in-quartz timescales are 10^{-12}-10^{-21} m/s; the slowest diffusivities produce rates that are slower than the slowest published rates for quartz and feldspars (10^{-15} m/s). We conclude that crystallization of the high-silica rhyolite was substantially shorter (≤10^3 a) than its source mush (10^4-10^5 a), and only the fastest Ti-in-quartz diffusion laws produce timescales consistent with geological constraints.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Magmatic timescales prior to the 2014-15 eruption at Fogo, Cape Verde: Insights from diffusion chronometry of olivines and clinopyroxenes

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Historical records from Fogo island (Cape Verde) reveal significant impacts of eruptions on the local population, including loss of livestock, destruction of buildings and farming areas and, occasionally, death of inhabitants. The limited volcano monitoring network and the lack of diffusion chronometry studies means there are significant gaps in our understanding of the timescales of magmatic processes at this active volcano. This research aims to enable better eruption forecasting and hazard mitigation at Fogo by using diffusion chronometry data from clinopyroxene and olivine phenocrysts in lava flows from the most recent eruption in 2014/15, to improve understanding of pre-eruption, magmatic timescales. Key research objectives are (i) to determine diffusion timescales from normally-zoned clinopyroxene and olivine crystals to understand magma and/or lava flow residence times and ascent rates; (ii) to determine whether there a link between seismicity and eruptions at Fogo through the comparison of diffusion timescales with recorded seismic activity. Initial findings include an assessment of diffusion chronometry methods which shows that published Fe-Mg diffusion coefficients underestimate timescales in Al-rich clinopyroxenes, such as those at Fogo. Initial results using published Mg self-diffusion coefficients, indicate clinopyroxene bands from the 2014-15 eruption formed ~305 days prior to eruption (based on 4 samples) and rims formed ~157 days prior to eruption (based on 14 samples). Diffusion chronometry from 16 olivine phenocrysts reveals timescales of hours in the lava flow for proximal samples, and up to 5 weeks for distal samples.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Kinetics of mafic magma ascent leading to monogenetic eruptions (Chaîne des Puys, France).

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Monogenetic volcanic fields are governed by a complex multi-reservoir plumbing system with common magma transfers and recharges that eventually trigger eruptions. Diffusion chronometry can reveal ascent timescales by using chemical elements that diffuse fast enough to be affected by decompression and associated loss of volatiles. Here we use the hydrogen content of olivines (SIMS measurements) to quantify such ascent rates for six scoria cones representing the mafic endmember of the Chaîne des Puys (France), an archetypal monogenetic intracontinental volcanic province (last eruption 6.7 kyr ago). We investigated the distribution of hydrogen in around twenty olivines from those edifices, and modeled the obtained profiles to derive ascent rates. H contents range from below detection limit (<3 ppm) to 20 ppm. The initial H concentrations in olivines were determined from coexisting melt inclusions. Solubility models highlight bubble nucleation depths of less than 5 km for water concentrations of 2 wt.% in the magma which rises from depths of ≥18 km. The measured H profiles vary from one crystal to another, with rims depleted in water compared to the core, reflected degassing water loss upon ascent. However, other H profiles are rather flat suggesting limited time for diffusion, complete homogenization or more complex degassing processes than simply water loss. Modeling diffusive re-equilibration of the H indicate mafic magma ascent range from few hours to about 2 days and ascent rates of around 0.13 m/s. These timescales are similar or slower than for stratovolcanoes in subduction zones or hot spots, for example.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Melt Loss by Repacking in Magma Mushes: Analogue Phase Separation Experiments and Natural Systems

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The mechanism by which crystal-melt mixtures separate is melt fraction sensitive and controls the physical and chemical evolution of magma mushes. Here, we present analogue phase separation experiments and samples from the Spirit Mountain Batholith (SMB) which show that in crustal magma reservoirs, separation by repacking (crystal rotation and translation) plays a major role. The experiments were conducted on mixtures of analog rigid particles and viscous liquid in a French press-like apparatus. During the experiments we monitor the samples with a video camera and an ultrasonic probe array and retrieve stress, strain rate, and bulk melt fraction. In SMB samples, fabric strength and estimates of trapped melt fraction using trace element modeling were obtained. Strains of ca. 10% were recorded between the start and end of experiments in the mush analogs. Particle-tracking analysis reveals that repacking is ubiquitous throughout the analog mush and that occasional jamming events must be overcome to resume repacking. Ultrasonic sensors were used to record acoustic emissions that accompany repacking. Similarly, repacking seems to play an important role in natural systems, as revealed by the correlation between trapped melt fraction and foliation development in SMB samples. Finally, the minimum trapped melt fraction calculated in the SMB is consistent with the that measured in the experiments (ca. 0.3). This value is consistent with the maximum packing fraction, which demarcates a transition from melt extraction by repacking (efficient melt extraction) to extraction by viscous creep (inefficient melt extraction).

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Homogeneous mush and sub-solidus carapace feed post-caldera volcanism within the Toba Caldera

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Among the uncertainties surrounding the dynamics of post-caldera magma systems, quantitative constraints on the spatiotemporal evolution of resurgent magmatic reservoirs and their connections to surface expressions remain poorly understood. The Toba caldera in Sumatra, the site of the largest supereruption in the last 2 Myr (Youngest Toba Tuff, YTT; ~75 ka), underwent magmatic resurgence shortly after the eruption, progressing from intra-caldera to extra-caldera locations. Previous studies suggest multiple sub-reservoirs contributed to the YTT supereruption and we test whether this is recorded in the nature, genetic relationships, and evolution of magmas feeding post-supereruption domes. This study combines zircon thermochronology ([U-Th]/He dating) and petrochronology (crystallization ages, trace elements, and oxygen isotopes) to investigate intra-caldera domes on Samosir Island, a crystal-rich enclave within one dome, and extra-caldera domes/volcanoes (e.g., Sipisupisu, Pardepur, Pusuk Buhit, and Sinabung). Zircon thermochronology from the central Samosir domes confirms post-YTT extrusion ages of ~64–68 ka. Petrochronological data reveal a magmatic history spanning 500 kyr, mirroring YTT magmas, with no evidence for heterogeneity within the footprint of the caldera. However, extra-caldera centers reveal heterogeneity. Zircon ages from the crystal-rich enclave cluster around 100 ka, contrasting with the host dome's inherited protracted crystallization history. These findings suggest post-supereruption domes were sourced from partially solidified remnants of YTT magmas that potentially originated from mush remobilization at ~100 ka. This study offers critical insights into pre- and post-caldera magmatic evolution and resurgence, advancing our understanding of some of the Earth's largest and most dynamic volcanic systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Investigating magmatic kinship and evolution in a recent arc-related explosive silicic conflagration: Volcán Huaynaputina and Ticsani in southern Peru

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Peruvian volcanoes Huaynaputina and Ticsani have produced large (VEI 6 and 4, respectively) dacitic eruptions during the Holocene and share similar mineralogical, chemical, and isotopic characteristics. Previous studies have suggested a genetic link between these volcanoes, proposing a shared magmatic reservoir at depth. Since large, long-lived magmatic systems at depth can sustain volcanoes capable of producing large explosive eruptions, understanding the potential petrogenetic relationship between Huaynaputina and Ticsani has significant implications for hazard assessments and interpretations of geophysical monitoring data. We further explore the hypothesis that these two magmatic systems are petrogenetically linked through U-series zircon geochronology. By comparing zircon age spectra, we seek to 1) determine if pulses of crystallization are contemporaneous across both systems and 2) compare the longevity of their crystallization histories. We also leverage zircon double-dating (U-Th/He) of previously analyzed grains to yield new eruption ages for Ticsani, whose eruptive chronology is poorly constrained. Preliminary U-Th disequilibrium ages for the Ticsani dacite reveals a long, episodic history of zircon crystallization that extends past 300 ka (the limit of the technique). Similarly, zircon from the 1600 AD eruption of Huaynaputina provides a record of crystallization spanning approximately 300 ka. These preliminary data showcase the long-lived nature of the magmatism at Huaynaputina and Ticsani. Zircon geochronology provides a novel perspective on these two volcanoes, offering new insights into the timing and tempo of magmatism and volcanism in southern Peru.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Longevity and Thermal Evolution of the Magmatic System Associated with the Cerro Blanco Volcanic Complex, Southern Puna: Insights from Zircon Petrochronology

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A central question in any effort to understand how large explosive eruptions (VEI ≥6) are generated is: How are the magma bodies that feed such eruptions assembled, and how long do they persist within the crust? Answering this requires understanding the longevity and accumulation rates of magma within the reservoir, as well as the temporal variations in the thermal state of the system (cold vs. hot storage). While geophysical studies provide a snapshot of the architecture of current magmatic systems, geological, geochronological, and petrochemical data allow us to understand the long-term evolution of these systems and the physical conditions that characterize both inter-eruptive and eruptive periods within their evolution. This contribution present zircon petrochronology results from the Cerro Blanco Volcanic Complex (Upper Pleistocene – Holocene), located in the Southern Puna. This volcanic center is one of the youngest and most productive rhyolitic caldera systems in the Central Volcanic Zone of the Andes (CVZ), with at least two eruptions (VEI ≥6) in the past 30,000 years. Our results indicate that all products of the Cerro Blanco Volcanic Complex were generated from a single long-lived reservoir (≥ 350 ka), which, while geochemically and isotopically homogeneous, was characterized by a complex thermal history, including marked contemporaneous internal heterogeneities. These internal variations, along with episodes of interstitial melt extraction during periods of high crystallinity in the system, explain the entire geochemical and textural variability within the eruptive products of the Cerro Blanco Volcanic Complex and their zircon populations.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.3: Timing and duration of magmatic processes

Allocated presentation: Poster

Understanding the Ecuadorian Rhyolite Province: A Petrochronologic Investigation of a Rhyolitic Flare-up in the Northern Andes of Ecuador

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Rhyolitic volcanism produces Earth's largest explosive eruptions and poses significant geohazards. The Ecuadorian Rhyolite Province (ERP), spanning 130 km from the Chacana caldera complex to Pisayambo, includes Chalupas and Cotopaxi Calderas. Located in the eastern cordillera, within an active andesitic volcanic belt in the Ecuadorian Andes, 25-50 km south and east of Quito, ERP rhyolitic volcanism initiated ~3.0 Ma. A flare-up occurred ~200 ka, producing the 200 km^3 Chalupas pumice flow and coeval rhyolitic flows. Subsequent events included rhyolitic lava flows and pumice lapilli fallout (100 km^3) in the northern Chacana Caldera and more recent eruptions at Cotopaxi (7 events between 9.6 and 2.3 ka), Conda (11.8 ka), and Aliso (<2 ka). This history of explosive activity highlights the need to understand better the ERP's magmatic evolution and implications for assessing future eruption risks to Quito and nearby areas. We are investigating the spatial and genetic relationships among volcanic centers to test the hypothesis that ERP rhyolites originate from a single magmatic system. Available whole-rock geochemistry and petrologic data are ambiguous but could support this hypothesis. To better address the hypothesis, we are conducting petrochronology (U-Pb, trace element, and O-isotope) analyses of zircons to track magmatic evolution and origin. Preliminary data suggests a significant overlap in zircon ages and chemistry across ERP rhyolites, connoting shared magmatic processes and a common source. Findings from this investigation will enhance the understanding of silicic magmatic systems in the northern Andes with implications for volcanic hazard assessment in the Quito region.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Talk [Invited]

Detecting Volcanic Activity on Venus through Magellan Radar Observations

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The surface of Venus has been shaped by intense volcanic activity, which may still be ongoing. Using radar data acquired by the Magellan mission, we analyzed multiple regions to investigate potential signs of recent volcanic processes. Among the areas studied, two regions displayed significant backscatter changes: the western flank of Sif Mons, a broad shield volcano, and the volcanic plain of Niobe Planitia. Cycle 3 radar images revealed backscatter increases of up to 10 dB compared to earlier cycles, with bright features overlaying darker pre-existing flows. Topographic analysis, integrating altimetric data and digital elevation models, confirmed that these features align with regional slopes, consistent with the emplacement of new lava flows during the Magellan mission. Change-detection techniques, based on minimum error thresholding, were employed to highlight these regions and distinguish them from unaffected areas. These results provide compelling evidence of geologically recent activity on Venus and support the hypothesis that the planet remains volcanically active. They also lay the groundwork for future high-resolution investigations. The upcoming VERITAS and EnVision missions are expected to bring substantial improvements in radar detection, enabling refined modeling of volcanic processes and the planet's surface evolution.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Talk

Io's Extraordinary Volcanoes: Epochal Changes Observed by Juno

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NASA's *Juno* spacecraft has provided vital observations allowing investigation of Io's extraordinary volcanic activity at global, regional and local scales. Here, we report volcanic changes on Io since the last *Galileo* (2002) and *New Horizons* (2007) flybys as observed by NASA's *Juno* spacecraft. We examine Io's volcanism down to the local scale (<10 km/pixel), drawing upon a catalog of thousands of hot spot detections at (currently) 328 individual locations identified in Jovian Infrared Auroral Mapper (JIRAM) image frames obtained between March 2017 and February 2024. We describe some of the more prominent areas of volcanic activity first identified or better resolved in *Juno* data (Tonatiuh, Lei-Kung Fluctus, Volund, East Kanehekili, Seth Patera, and others), examining appearance, volcanological and geological settings, observed thermal emission, and evolving behavior, quantifying the changes that have taken place. At Tonatiuh we have used JunoCam and Stellar Reference Unit (SRU) data to provide context; at East Kanehekili, we combine observations from multiple assets, incorporating data from the James Webb Space Telescope and Keck telescope, to provide a more comprehensive understanding of the evolution of a specific eruption. We further examine different types of active paterae, including activity in the lava lakes at Pele and Loki Patera. We identify a group of bright eruptions whose spatial and temporal locations might suggest regional clustering. Our estimates of volcanic thermal emission are broadly consistent with previous analyses of spacecraft data. Part of this work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Talk

Volcanic activity and its related subsurface magma-feeding system in Central Elysium Planitia, Mars

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The diversity of mantle plumes across different terrestrial bodies (i.e., Venus, Earth, and Mars) draws the attention of researchers in planetary science and volcanology. Recent studies have proposed the existence of an active mantle plume beneath one of Mars's youngest regions, Central Elysium Planitia (Broquet and Andrews-Hanna, 2023). Central Elysium Planitia (hereafter CEP) has exhibited effusive volcanic activity over the past 250 million years (e.g., Vaucher et al., 2009). Recent seismic observation suggests possible current volcanic activity in this region (e.g., Stähler et al., 2022). In this study, we especially focus on low shields (small shield volcanoes, hereafter referred to as LSs) and aim to reconstruct the volcanic history and the subsurface magma feeding system at CEP. By crater counting, we estimate the surface age of LSs to be after 100 Ma, and most of them are after 30 Ma. Our analyses of geomorphology, spatial distribution, and the surface age of volcanic units suggest that: 1. The dense-rock equivalent (DRE) of volcanic units in CEP underwent changes following the Marte Valles lava effusion, which occurred around 10 Ma. 2. The spatial distribution of LSs is influenced by a magma-feeding system that dynamically interacts with the regional stresses induced by the proposed active mantle plume. In this presentation, we will discuss these findings and explore the history and subsurface systems associated with the latest volcanic activity on the red planet.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Talk

Influence of lava flows on the global evolution of Venus

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Lava flows on Venus can be exceptionally long, far surpassing those on Earth. Radar data from NASA's Magellan mission revealed flows extending hundreds to thousands of kilometres. Previous numerical models have shown that magmatism and crustal production significantly influence planetary tectonics. For example, extrusive volcanism helps breaking tectonic plates facilitating plate tectonics on rocky planets (Lourenço et al., EPSL 2016), while intrusive magmatism has been found to lead to a new global tectonic mode entitled "plutonic-squishy lid". This mode divides the lithosphere into small blocks that move across the surface due to lithospheric drippings and delaminations, even in the absence of active subduction (Lourenço et al., G3 2020). Notably, this regime might apply to Venus (e.g., Byrne et al., PNAS 2021; Smrekar et al., Nat. Geo. 2022). However, previous numerical models of lithospheric and mantle evolution have not considered lateral lava spreading, instead assuming that crust is always formed above eruption sites. Here, we extend the global mantle convection code StagYY (Tackley, PEPI 2008) to incorporate lateral lava spreading and analyse its effects on Venus' evolution. We study how varying lateral lava spreading angles impact crust and lithospheric thickness, mantle temperature, surface heat flow, eruption rates, and outgassing history. Additionally, we explore how lava flows influence Venus' tectonic regime, a subject of ongoing debate (e.g., Rolf et al., Space Sci. Rev., 2024). Our models produce a range of predictions that can be tested by future missions to Venus, including EnVision measurements by the VenSpec spectrometers, comprising outgassing and surface composition.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

High-resolution investigation of small volcanic features can deepen our understanding of eruption dynamics on Mars

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To provide new and previously inaccessible insights into the volcanic evolution on Mars, we must utilize recently acquired high-resolution orbital images. These, using stereo-pairs, enable the production of digital elevation models (DEMs) which are powerful datasets for precise morphological analyses of landforms, revealing volcanic features that were previously unknown or only inferred. Specifically, the vast and young volcanic regions of the Tharsis province offer the best natural laboratory for characterizing late Amazonian (<300 Ma) volcanism. Although Tharsis predominantly consists of effusive landforms, such as low shield volcanoes and their associated lava flows, recent imagery and DEMs have allowed us to identify multiple young features formed by simultaneous explosive and effusive eruptions. These features are primarily composed of steep-sided, vent-proximal accumulations of ejected pyroclastic material, which could have been modified by syn- or post-eruption processes, resulting in morphologically diverse landforms that were previously overlooked. Since these deposits are attributed to the summit vents, they must have formed simultaneously with, or after, the downslope spreading lava flows that constitute the edifice slopes, which have been dated to less than 100 million years old. Therefore, our investigations extend the value of orbital Martian data and enhance our understanding of the dynamic vent-proximal eruption environments that have occurred on Mars in the recent geological past. We provide direct evidence of the role of explosivity in the evolution of young low-shield volcanoes in the largest volcanic province, Tharsis, and show how the widespread identification of explosive eruption deposits can inform on planet-scale volcanic evolution.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

Sinuous Volcanic Channels on Tharsis Montes (Mars) Rift Aprons

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Lava channels 100s of kilometers in length, observed on Venus, the Moon, and Mars, display morphologies suggestive of thermo-mechanical erosion. Exotic lava compositions and high effusion rates have been proposed to explain these features. On Mars, the spatial distribution, morphology, and emplacement conditions are key to understanding the planet's interior and surface evolution. For this study, we focus on sinuous channels on the Tharsis Montes (Arsia, Pavonis, and Ascreaus) rift aprons, landforms constructed by effusive volcanic deposits formed after the shield-building phase of the Tharsis Montes concluded. The aprons represent an understudied region with relatively young deposits. We delineated rift apron subregions using previous literature (e.g. Plescia 2004) and changes in slope and flow direction. An initial survey conducted using THEMIS IR and CTX data located 350+ features. We ranked the features using a confidence scale: 1 = very unlikely volcanic and 5 = very likely volcanic, based on morphology and regional context with ~100 volcanic channels confirmed. On the southern rift apron of Ascraeus Mons, extending from an elevation of ~5.6 - 8.3 km, we have identified 30 volcanic channels. Channels range in length from ~7.5 - 240 km with a mean length of 50 km and a median length of 26 km. Regional slopes range from ~0.3 - 2°. This suggests that long-lived effusive eruptions were part of the later evolution of the large shield volcanoes on Mars. Our work is ongoing as we continue to characterize and quantify channel morphology.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

New science results about extremely active volcanism on Jupiter's moon Io: Implications for future exploration

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Recent Io results have come from telescopic observations and from Io flybys by the *Juno* mission. De Kleer et al. (2024, Science 384) used submillimeter observations of Io's atmosphere to measure sulfur isotopes and found $^{34}S/^{32}S$ to be highly elevated compared to average Solar System values. They interpret this to mean that Io has lost 94 to 99% of its available sulfur and has been volcanically active for most of its history. *Juno* observations show new eruptions (Ravine et al., in progress) and revealed that many hot spots consist of hot rings suggestive of lava lakes (Mura et al., in press). The *Juno* and other data shows the polar regions may be less active than equatorial regions (Davies et al., 2024, PSJ 5), important to understanding the depth of tidal heating, but *Juno* cannot detect all of Io's heat flow and longer-wavelength observations are needed. *Juno* acquired gravity data to measure tidal k_2 as a test for a magma ocean with a detached lithosphere (Park et al., in progress). New models for the distribution of melt in Io may be needed to satisfy the gravity result, the induced magnetic signature (Khurana et al., 2011, Science 332), and other observations. The *Io Volcano Observer* mission completed a Phase A study for Discovery in 2021 and was updated in 2023 for a New Frontiers 5 opportunity (Hamilton et al., PSJ in progress). We will discuss how a future Io-dedicated mission could address the science questions raised by the new results.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

Modelling displacement and fracturing dynamics around magma intrusions: laccoliths on the Moon, Mars, and in the Polish Sudetes

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Intrusive domes on the Moon and Mars indicate that laccoliths have deformed and fractured the shallowest 1-2 km of crustal rocks and the surface, similar to those on Earth. However, numerical models only broadly approximate crustal mechanical properties and do not explicitly simulate fracturing. The effect of heterogeneous crustal strength, intrusion depth, and specific gravity forces on laccolith emplacement dynamics remains thus unclear. We have simulated laccolith inflation in a particle-based assemblage with a two-dimensional (2D) Discrete Element Method (DEM). The DEM allows us to investigate magma-induced displacements, high strain concentrations, and dynamic fracturing. We have systematically varied host rock strength and gravitational acceleration. We also applied our model to Permian trachyandesite intrusions in the Polish Intra-Sudetic Synclinorium. There, we sampled intact sedimentary host rocks and measured their mechanical properties in laboratory experiments. We upscaled the intact sample properties to the bulk rock properties in our 2D DEM model by using either the Geological Strength Index or a randomly cracked model. Our results displayed a spectrum of displacement, strain, and fracture patterns between a highly fractured and a poorly fractured end-member. Also, the same amount of laccolith inflation induced more vertical surface displacement at the lower lunar gravity in stiffer rocks. Rock strength controlled the amount of fracturing more than gravitational acceleration. Pre-existing cracks concentrated shear strain and syn-intrusive fracturing in narrower zones. Crustal heterogeneities and gravitational acceleration thus affect the relationship between surface deformation features and laccoliths and are essential factors when modelling laccolith inflation.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

Comparative analysis of surface roughness in lava flows on Mercury and signatures from Hawaiian volcanic terrain

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Surface roughness is a key indicator of volcanic flow properties and eruption dynamics, with terrestrial basaltic flows in Hawai'i offering valuable analogs for planetary studies. Using MESSENGER's Mercury Laser Altimeter (MLA) data, we investigate the roughness of Mercurian lava flows to better understand Mercury's volcanic history and compare it to LiDAR-derived surface characteristics of Hawaiian basalts. This study aims to assess whether variations in surface roughness of Mercurian lava flows, despite modification by impact gardening, align with broader-scale features observed in Hawaiian basaltic terrains, providing insight into flow dynamics and volcanic activity. We analyze MLA topographic data for regions on Mercury with volcanic plains, applying roughness metrics comparable to those derived from terrestrial studies of Hawaiian basalts. Metrics such as height deviation and slope variation are used to evaluate Mercurian flow characteristics and their potential correlation with the surface morphologies of basaltic lava flows in Hawai'i. Preliminary analyses indicate that the roughness of Mercurian lava flows exhibits spatial variability that may correspond to terrestrial analogs, with smoother regions potentially reflecting Pāhoehoe-like flows and rougher areas resembling 'A'ā-like flows, despite surface-altering processes. By relating Mercury's surface roughness to the morphologies of Hawaiian lava flows, this study provides insight into Mercury's volcanic processes and the broader implications of planetary lava flow dynamics. Our findings suggest that even under varying planetary conditions, surface roughness can serve as a comparative tool, bridging terrestrial and planetary volcanology.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

A magmatic origin for floor-fractured craters in the Southern Highlands of Mars

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Lunar floor-fractured craters (FFCs) possess fractured and uplifted floors and result from shallow, crater-centered, sill-like intrusions. FFCs have been observed on Mars, mainly in the Southern hemisphere, where the crust is thicker and of enigmatic composition. However, the complex geologic history of Mars makes it difficult to assess with certainty their magmatic origin as interaction with groundwater or ice could produce similar structures. Here, we study a set of FFCs located in the Martian Highlands. We show that their floor uplift evolves following the square root of the total length of their floor fractures, as predicted from a physical model of fracture formation from a sill intrusion, similarly to lunar FFCs. This suggests that these FFCs are of magmatic origin. On the contrary, extrusion of mafic magma is observed in the interior of Jezero, a crater located in the same region of Mars, though on a thinner crust. In both cases, the process is crater-centered, suggesting that the magma is negatively buoyant in the crust. We use a model of dyke propagation in an elastic crust, considering the stress field caused by the crater unloading, to study the dyke path below the crater. We demonstrate that a simple difference in crustal thickness can explain the horizontal deflection of dykes into sills below FFCs and the extrusion of magma in the interior of Jezero. We finally show that the crust must be lighter by 100-150 kg m^3 than the magma for FFCs to form in the Highlands.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

The role of volcanism and mantle dynamics in the long-term evolution of Venus' atmosphere: outgassing and volatile sink.

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Despite similarities between the two planets, Venus' hostile surface conditions are strikingly different from Earth's, and a direct consequence of its thick CO_2-N_2 atmosphere. A non-negligible portion of the greenhouse effect leading to high surface temperatures is caused by the tiny relative amount of atmospheric water it contains (about 20 ppmv, while free oxygen is practically absent). We investigate the origins of the present-day atmosphere of Venus by focusing of the sources and sinks of various gas species, with a specific eye for the role of volcanism. In this work, long-term evolution, interior evolution and atmosphere bulk composition are tracked using StagYY mantle dynamics models to calculate volcanic melt production and interaction with the atmosphere. Important volatile-exchange mechanisms include atmosphere escape mechanisms, volcanic outgassing, and gas–surface chemical reactions through oxidation of fresh lava. We estimate volatiles fluxes necessary to obtain the observed Venus conditions at present-day. Low outgassing fluxes of water are required, while that of CO_2 and N_2 remain poorly constrained. From present-day measurements, non-thermal mechanisms can account for the loss of 4 mbar to a few bar of oxygen, over 4 Gyr. The trapping of oxygen on the surface by oxidation of newly emplaced volcanic material depends on lava composition, lava flow geometry and the oxidation efficiency. While oxidation is fast, it appears limited to a thin layer of material, which limits the overall oxygen sink, for a total loss of O that is similar to that from non-thermal escape.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

Magmatic and Tectonic Processes in Amazonis Planitia: Implications for Late Amazonian Volcanism

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Pit chains in Amazonis Planitia occur within geologically recent (i.e., Late Amazonian) volcanic units. These pit chains appear to be the source of some local lava flow units, which is unexpected given that the location is nearly midway between the Tharsis and Elysium volcanic provinces and has previously been considered a sink for flows sourced from the surroundings rather than a volcanic source region itself. However, the pit chains and flow units are located near the intersection of two major strike-slip fault systems, suggesting a link between magmatic and tectonic processes in the region. This work presents: (1) regional geologic mapping of central Amazonis Planitia to establish a context for observed pit crater chains and flow units; (2) detailed facies mapping of the pit crater chains, including detailed topographic and volumetric analysis using stereo-derived digital terrain models; and (3) modeling of strike-slip faulting processes to assess if observed dilatational extension at the fault intersection could have generated extensional stresses conducive to magmatic ascent. Results show that the lava channels feeding flow units near the fault intersection dip back toward the axis of the pit crater chain, which can be explained by syn- and/or post-emplacement subsidence of an underlying magma chamber. These results further imply that tectonic processes strongly affect the locations of magma migration through the martian crust, thereby leading to volcanic activity that is more widely spread than previously believed.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

Insights into volcanism on Io using sulfur isotopes

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Jupiter's moon Io is the most volcanically active body in our Solar System, but it is difficult to constrain when volcanism started on Io because Io's dynamic atmosphere and high resurfacing rates leave it with a young surface. Io's volcanoes emit vast quantities of sulfur into its atmosphere, which is either lost to space or buried in the crust and recycled. We combine a numerical model of sulfur's isotope cycle with telescope measurements of the sulfur isotope composition of SO_2 in Io's atmosphere to model the evolution of sulfur isotopes over time and therefore how long volcanism has been occurring. The highly isotopically enriched signature of Io's atmosphere ($\delta^{34}S$ = +347 ± 86 ‰) indicates Io's volcanoes have been active for most its 4.5-billion-year history. Although volcanic processes are not the main cause of isotopic fractionation on Io, volcanism is crucial to cycling sulfur between the atmosphere and the mantle. This means Io's sulfur cycle is well approximated by Rayleigh distillation, enabling extreme isotopic enrichments over time. Also, the heat from volcanism drives SO_2 reaction with crustal rocks such that sulfur can be locked into the crust and founder into the mantle. We predict that volcanic plumes on Io may have variable $\delta^{34}S$ depending on whether they are sourced from mantle magmas or remobilising sulfur in the crust. Observations of atmospheric variations in $\delta^{34}S$ with time and/or location could reveal the average mantle melting rate and hence whether the current volcanism rate is anomalous compared to Io's long-term average.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

Shallow Cryovolcanic Melt as a Test of Subduction in Europa's Ice Shell

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Europa is an icy moon of Jupiter whose surface is tectonically active. Kattenhorn and Prockter [2014] suggest a region of this active surface is mobile and undergoing subduction into Europa's subsurface. Evidence for subduction includes the mapping of smooth, lobate flows on the identified overriding plate as potential cryovolcanic flows. However, flux melting (which drives arc volcanism on Earth by releasing water into the overlying mantle) is not relevant to icy subduction. Here, we test different subduction-induced melting scenarios on Europa using other melt formation mechanisms, such as heating via friction or the incorporation of relevant Europan salts into the subducting slab. We use a one-dimensional subduction model to evolve temperature through time to track change in temperature as an icy slab subducts into Europa's subsurface. Additionally, we measured that putative cryolavas extend 90 km away from the margin, meaning the subduction angle must be shallow (4.4–18.4°) to provide melt to form the lavas. We find melt can form as shallow as 4 km in Europa's subsurface, which is 26 km shallower than the depth of the ocean (if Europa's ice shell were 30 km in thickness). Overall, we find that shallow melt from subduction is feasible in an icy subduction scenario with the aid of frictional heating and salt. We predict that if there is cryovolcanic melt formed from subduction in the region proposed by Kattenhorn and Prockter [2014], the upcoming Europa Clipper mission could use its radar instrumentation to look for cryomagma at our predicted depths.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

What is the eruptive flux on Venus? Comparison with Earth and Suggestions for Targeted Observations by VenSAR

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Estimates of the global volcanic output on Venus vary widely (0.01-10 km^3/year). The VenSAR (Venus Synthetic Aperture Radar) instrument launches on the EnVision spacecraft in 2031. We ask: how well will it quantify volcanic flux? We use the size-frequency distribution and deposit dimensions from large eruptions on Earth, augmenting the size by 75% for the higher temperature and pressure on Venus (Flynn et al., 2023). We find that ~100% of these eruptions would be detectable with VenSAR-VenSAR imaging and ~90% with VenSAR-Magellan. However, even if volcanic activity is spatially resolved, the radar images must show observable change. We examine SAR amplitude changes at 25 basaltic terrestrial lava flows using different polarizations from European Space Agency's Sentinel-1a/b satellites. Only 56% of deposits were detected for any polarization, suggesting that detecting and mapping new deposits on Venus will be challenging. The difference in wavelength and incidence angle also impact the detectability of surface change. We will employ scattering theory to extrapolate their impacts on flow detectability. Targeting VenSAR at the right volcanoes is critical. If all eruptions were the same size, a sampling of a small number could be sufficient. Eruption size on Earth and Io vary by orders of magnitude, so we need to measure a range of eruption sizes on Venus. Assuming a size-frequency distribution similar to Earth and Io, if VenSAR images the 20-40% most active volcanic features, we could detect 79-92% of the mass flux. If we target the least active, we would detect zero.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

Understanding Explosive Eruptions Dynamics on the Moon from the Textural Analysis of 74001/2 Glass Beads.

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Investigating the physicochemical processes behind explosive lunar volcanic eruptions is important for understanding the volatile budget and the evolution of the interior of the Moon. The 70 cm, 74001/2, drill core collected from Taurus-Littrow Valley during Apollo 17 mission, provides a unique opportunity to study explosive lunar volcanism. We analyzed the physicochemical characteristics of glass beads from ~18, ~36.5 and ~57 cm depths within this core using an optical microscope, SEM, and EPMA. Our study reveals that the core consists of orange volcanic glass beads and its chemically equivalent crystalline black beads. The beads are chemically homogeneous, confirming their volcanic origin with a MgO/Al_2O_3 ratio > 1.6 and a CaO/Al_2O_3 ratio > 0.75. Studied samples show the presence of vesicles throughout the core. Vesicle (gas bubbles in magma) characteristics, such as size, shape, and coalescence textures, can help unravel the eruption dynamics that generated the lunar glass beads and yet have remained poorly constrained. We use bubble coalescence timescales to constrain the cooling rates of the glass beads. Using a free-flight cooling model, we find that if coalescence began near the liquidus temperature, cooling rates exceeding 1000 K/s were required for rapid quenching to preserve the observed textures. A delayed coalescence at ~1530 K would have allowed bubble coalescence but could have resulted in an incomplete film retraction, matching the observed textures. The implications of our findings on the dynamics of the lunar explosive eruptions and any possible presence of gas plumes or transient atmosphere are discussed.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.4: Volcanism across the Solar System

Allocated presentation: Poster

Major, Early Volcanism on Terrestrial Planets

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The earliest preserved crust on Mercury is about 4.2 billion years old. The apparent lack of surface materials predating this point is attributed to resurfacing from some combination of major bolide impacts and volcanism. At present, about 27% of the surface of Mercury is occupied by “smooth plains” terrain, the majority of which is thought to be flood lava flows. Most of the remainder of the surface is covered in “intercrater plains”; these units, although much more cratered than the smooth plains, are also predominantly volcanic, also emplaced as flood lavas. The geological record of Mercury thus indicates that the planet’s crust was rapidly built following the magma ocean phase, with eruptive rates and fluxes rapidly waning even before the planet entered a state of global contraction. On Mars, the oldest preserved crustal materials are interpreted to comprise reworked volcanic sediments, implying an even earlier phase of major crust-building by flood-mode volcanism. Even on the Moon, where recognised volcanic activity is primarily restricted to giant impact basins, basaltic lavas were being erupted on the lunar farside as early as 4.2 billion years ago. There is no identified ancient crust on Venus, and the earliest markers of volcanic activity on Earth are detrital zircon crystals. Nonetheless, by comparison with Mercury, Mars, and even the Moon, it is likely that the very earliest eras of Venus and Earth following magma ocean solidification were characterised by eruptive fluxes unlike anything that remains on the surfaces of any of these worlds today.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Talk [Invited]

Magnetotelluric Imaging of the Magma Plumbing System below the Ubinas Volcano (Southern Peru)

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The Ubinas volcano, located 75 km east of the city of Arequipa, is the most active volcano in Peru. Its last eruption occurred in 2019, and since July 2023 it has been undergoing a new eruptive phase. Petrological studies suggest the presence of a Holocene magma storage region at depths of 3–10 km b.s.l., with a primitive magma deposit located at depths greater than 25 km b.s.l. At shallower depths (2–4 km a.s.l.), self-potential observations indicate an extensive hydrothermal system. To identify the resistive structures beneath the Ubinas volcano and build upon previous studies, we (IGP-IRD) acquired 25 broadband magnetotelluric (MT) data (period range 0.001-5000 s) in 2022. All data were processed using a robust and remote-reference approach, and a 3D resistivity model was obtained by inversions of full impedances, tippers, and phase tensors using the 3D MODEM code in frequency range between 0.0004-1000 Hz. Phase tensor inversion allowed for static shift correction. The inversion converged with a normalized RMS = 1.21. The 3D model reveals a prominent conductive zone (C1: 6–10 Ωm), located approximately 10 km below the surface (5 km b.s.l.) and northeast of the volcano. This zone is tentatively interpreted as the magmatic reservoir, which agrees well with petrological studies. Near the surface, a conductive body follows the volcano's topography, consistent with hydrothermal systems (C2: 1–8 Ωm). These results were correlated with the earthquakes detected between 2018 and 2023, showing that seismic activity suggests pathways for magmatic fluids ascending to the surface during the current eruptive phase.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Talk [Invited]

Volcano-tectonic processes in the on-going Reykjanes peninsula volcanic episode as revealed by joint analysis and modeling of seismic and deformation data

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The N-America-Eurasia Plate Boundary (PB) along Reykjanes peninsula, Iceland, strikes ~N75-80E^0, and intersects four ~NE-SW striking volcanic systems, including Reykjanes-Svartsengi and Fagradalsfjall. ~1.9 cm/year spreading towards ~N105E^0 is oblique to the PB, requiring left-lateral slip along the boundary, but most slip occurs on N-S oriented, strike-slip faults. Since December 2019, release of tensional stress accumulated over 800 years has been triggered by magmatic intrusions into the upper crust beneath Fagradalsfjall and Svartsengi, causing 10 dike intrusions and volcanic eruptions, slip on the PB, and intense seismicity. Migration of high-precision relocated seismicity reveals location of magma up-flow near the PB beneath Fagradalsfjall, subsequent repeated inflow into vertical dikes propagating several kilometers NE and SSW and finally erupting. Distribution of magma within the dikes is determined from inversion of InSAR and GNSS data. The intruding dikes have triggered slip on near-by faults releasing earthquakes up to M_W5.6, which in turn have triggered slip over large sections of the PB, as confirmed by seismicity and interferograms. Relocated seismicity patterns in 2020 and October 2023, suggest magma from below Fagradalsfjall may have flowed west and upwards, accumulating in a magma domain in the shallow crust adjacent to the PB at Svartsengi, until breaking out on November 10th, forming the first dike intrusion at Sundhnúkur crate-row. Major tectonic rifting, generating ~30 $M_W \geq 4$ earthquakes accompanied the dike formation near Grindavík village, causing major surface fracturing and subsidence. Recharging of the domain has led to 7 more dike intrusions and eruptions along parts of the initial dike.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Talk

Exploring Magmatic Evolution by Linking Field Data to a Magma Dynamics and Forward Geophysical Model at the Three Sisters Volcanic Complex, OR, USA

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The Three Sisters volcanic complex in the central Oregon Cascades is considered a "very high threat" by the U.S. Geological Survey, with eruptions of South Sister as recently as 2,000 years ago and inflation just west of South Sister since the mid-1990s. Geodetic models suggest the source of inflation is 5–7 km deep, and most models require some component of magmatic intrusion, perhaps into an existing magma reservoir. We conducted a Bouguer gravity survey to image the hypothesized shallow magma system and potentially discriminate between a predominantly magmatic versus hydrothermal deformation source. To further explore the evolution of the Three Sisters magma system to its current state of activity, we compare these gravity data to model scenarios using a coupled magma dynamics and forward gravity modeling approach. Evolution of the Three Sisters magmatic system is modeled via a 3D multiphase numerical model with additions of stochastic intrusions. The thermal phase equilibria of the intrusions produce magma bodies with a density contrast to the background crust, creating a model gravity anomaly at the surface of the simulation that is compared to the Bouguer measurements. We explore a range of primitive magma fluxes as well as strictly intrusive scenarios and those that consider eruptions. We seek the range of plausible average mantle flux rates, volumes, and depths of magma required to produce the current gravity signal. Additionally, we consider forward resistivity and seismic velocity models for the magmatic histories that best fit the gravity data to highlight opportunities for future geophysical studies.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Talk

Separating Magmatic and Hydrothermal Sources in Volcanic Deformation

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Determining whether unrest at silicic systems is primarily driven by magmatic, hydrothermal, or a combination of both is crucial for assessing eruptive hazards, although remains a long-standing debate at many well-studied systems. Recent advances in machine learning and satellite technology, especially through the Sentinel-1 mission, allow for more detailed analysis of spatial and temporal deformation patterns, enabling us to separate signals with different characteristics. In this study, we use spatial Independent Component Analysis (sICA) to separate the magmatic and hydrothermal contribution to surface deformation based on their different spatial characteristics. Using Corbetti Caldera, Ethiopia, as a case study, we extract two distinct surface deformation patterns, related to a steady uplift of 5.1 cm/year linked to a shallow magmatic source, and a laterally bound hydrothermal signal with a seasonal amplitude of 0.65 cm. We found that while the original data can be modelled well using single Mogi point source, sICA demonstrated that a two-source model provides a better solution. These findings highlight the potential of combining high-spatial and temporal resolution datasets with machine learning techniques to separate magmatic and hydrothermal processes in the surface deformation. Understanding the cause of unrest provides critical insights for hazard assessment.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Talk

Seismic constraints on the magmatic system beneath Changbaishan intraplate volcano, China/North Korea

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Changbaishan volcanic field is located on the border between China and North Korea, consisting of three polygenic volcanoes (i.e., Tianchi, Wangtian'e and Namphothe) and over 200 monogenic volcanoes. Changbaishan volcano field is one of the most intriguing and hazardous volcanoes on Earth owing to its voluminous Holocene activities and unusual magma composition within a continental intraplate setting. There is a growing concern about the potential eruption of the Tianchi volcano in recent years, but the magmatic system beneath Changbaishan volcano field remains hotly debated. In this study, we present a high-resolution 3-D crust and upper mantle S-wave velocity model beneath Changbaishan volcano field based on unprecedented regional dense seismic arrays. The S-wave velocity structure revealed two prominent low-velocity anomalies in the crust and upper mantle beneath Changbaishan volcanic filed. The low-velocity body beneath the Tianchi volcano extends from the surface to the lower crust, while the low-velocity anomaly beneath the Wangtian'e volcano is situated in the mid-lower crust. The middle-lower crustal low-velocity body is interpreted to be the main magma chamber that may feed the surface volcanism and hydrothermal activities. The upper mantle low-velocity zone is representative of upwelling asthenosphere. We propose that the intraplate volcanism of Changbaishan volcano field is driven by the decompression melting of upwelling asthenosphere, which could originate from the mantle transition zone as suggested by previous large-scale tomographic studies.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Talk

Unraveling Pavlof Volcano's Shallow Plumbing System: Insights from Seismoacoustic and Multidisciplinary Analyses

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Pavlof Volcano, a frequently active volcano in the Aleutian arc, has erupted six times within the past two decades (2007, 2013, 2014, 2016, 2021–22). Many Pavlof Volcano eruptions lack precursory seismicity or detectable ground deformation, making them challenging to forecast. Since 2007, these eruptions have ranged from Strombolian to sub-Plinian (VEI 2–3), with their characteristics seemingly related to their active vent location, which switches between the southeast flank and summit crater. To better understand Pavlof Volcano's plumbing system and improve eruption forecasts, we integrate geophysical, petrologic, gas, and satellite-based thermal infrared data to conduct a multidisciplinary synthesis of its past six eruptions. Notably, our newly developed tremor detection model, the VOlcano Infrasound and Seismic Spectrogram Network (VOISS-Net), reveals unique pre- and co-eruptive seismic tremor regimes associated with each vent system. Local infrasound data and air-to-ground coupled waves used to refine explosion catalogs also uncover evidence of gas-rich explosions from the summit vent previously thought to be inactive during the 2021–22 eruption. Whole-rock composition and ash analyses indicate a near-uniform basaltic andesite composition spanning multiple eruptions, and a consistent anomalous presence of decayed olivines in erupted material. These findings lead us to propose a new conceptual model for Pavlof Volcano's plumbing system: a shallow T-junction outlet controlling seismic tremor diversity and the partitioning of gas-charged magma, and an elongated, heated conduit transporting magma from depth and facilitating solid-state diffusion of recycled magma between eruptions. We suggest magma ascent rate and conduit plugging modulate the eruption styles seen at Pavlof Volcano.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Talk

The magma storage capacity of Mt. Etna plumbing system tracked from 3 decades of compositional lava evolution and excess SO2 discharge

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Deciphering the magma plumbing system of volcanoes is crucial to improved understanding and forecasting of their eruptive behavior. Here we provide a quantitative estimate of the magma storage capacity beneath Mt. Etna by combining the remarkable compositional evolution of erupted lavas over three decades since the early 1970s and the excess SO_2discharge during this period. Focusing on K_2O/Th and Rb/Th ratios (unaffected by the degree of magma differentiation) in pre- and post-70s Etna lavas, we document in detail the progressive replenishment of Etna's mid-crustal plumbing system by a new, more alkaline and more radiogenic trachybasaltic magma that gradually mixed with and replaced the former resident magma. On a few occasions (1974, 1998, 2001-2002) this new magma could bypass the central volcano conduits and reach the surface with no or limited interaction with the resident magma. Instead, on other occasions the imprint of resident magma turned back to increase, indicating a complex storage system geometry. Termination of the compositional lava change after the 2001-2002 eruptions, and broadly steady K_2O/Th and Rb/Th ratios in products erupted since then, demonstrate a complete renewal of Etna's magma storage cell. Combining this compositional trend over 3 decades with the cumulated amounts of co-erupted magma and of degassed magma - inferred from SO_2 emission rates - constrains an overall magma storage capacity of order 4 km^3 beneath Etna, a main proportion of which consists of unerupted degassed magma. Useful comparison can be made with recent results from seismic tomography and ground deformation modeling.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Using satellite geodesy to understand magmatic architecture and rheology

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Satellite technology has revolutionised the coverage, resolution and frequency of deformation. Dense time-series of high-resolution images reveal complexity and diversity than was not apparent when only infrequent point measurements were available and are more compatible with the paradigm of extensive multiphase, magmatic systems. Here we integrate thermal models of crustal-scale magma evolution with thermo-mechanical simulations of ground deformation. This allows us to determine the influence of long-term magmatic flux over 10^5-10^6 years on viscoelastic deformation patterns spanning a10-year observation period for a range of overpressure source depths. Our results reveal a coupling between surface deformation and the protracted thermal evolution of magma systems, modulated by magma flux and system lifespan. Variations in plumbing system architecture contribute to diverse surface deformation styles at different volcanoes. Relatively cold magma systems (~750℃ after 1Ma) exhibit cycles of uplift and subsidence, while comparatively hot plumbing systems (~900℃ after 1Ma) experience solely uplift, albeit at decaying rates. These findings align exceptionally with independent geophysical and geodetic observations from case study caldera systems in the East African Rift, emphasizing the potential of surface deformation measurements as tool for deciphering the physical state and architecture of magmatic plumbing systems. Our study emphasizes that considering long term magmatic system evolution is imperative for accurate interpretation of volcanic unrest signals.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Highly Siderophile Elements and 187Os/188Os from Hawaiian Cumulate Xenoliths Show Potential Mixing Between the Loa and Kea Trends

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Studies of shield-stage lavas have established that there exist two distinct geochemical trends in Hawaiian volcanoes referred to as the 'Loa' and 'Kea' trends [1, 2]. These trends are isotopically distinct endmembers that have been best defined by long-lived Rb-Sr, Sm-Nd and U-Th-Pb isotopes [1, 2]. We report new $^{187}Os/^{188}Os$, highly siderophile element (HSE: Re, Pd, Pt, Ru, Ir, Os) abundances, and bulk rock major and trace element abundance data for ultramafic cumulate xenoliths from Mauna Kea (Kea trend), Mauna Loa, and Hualalai (Loa trend). These samples provide the strongest constraints yet on $^{187}Os/^{188}Os$ for the Loa and Kea trends. Loa trend xenoliths have more radiogenic Os (Avg = 0.1342 ±0.0043; 2σ n = 8) than Kea trend xenoliths (Avg = 0.1270 ±0.0062; 2σ n = 10), consistent with higher time integrated Re/Os for the Loa trend mantle and a recycled oceanic crustal component. These new results show there are no clear distinctions between absolute or relative HSE abundances between the two trends, but there is clear distinction in long-term Re/Os between the mantle sources. However, seismic and gravity studies suggest the presence of shared magma chamber and/or plumbing systems between volcanoes of Loa and Kea trend composition [3]. These observations seem to contradict the available geochemical and isotopic data. Here, $^{187}Os/^{188}Os$ mixing models are used to address the viability of different mixing scenarios. [1] Abouchami et al. (2005) *Nature*, *434*(7035), 851; [2] Weiss et al. (2011) *Nature Geoscience*, 4(12), 831; [3] Wilding et al. (2023) *Science, 379*(6631) 462-468.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Imaging the trans-crustal(?) magma system in models and in the Cascades

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Most eruptions at arc volcanoes are proximally supplied from crustal magma reservoirs, although their depths and volumes are often poorly constrained. Geophysical imaging has been able to identify zones of melt accumulation in some cases, but often different imaging methods produce conflicting results, complicating comparisons between different volcanoes. To better understand the strengths and limitations among different geophysical imaging methods, and to compare them with petrological approaches, we generate a notional trans-crustal volcanic model based on common conceptual diagrams. This model system has petrologically consistent variations in bulk composition, temperature and melt fraction, all of which are converted to geophysical observables such as seismic velocity and electrical conductivity. We explore the extent to which the entire plumbing system can be imaged, and find that many common methods have high sensitivity to the upper crustal reservoir but not the entire system. As a demonstration of such imaging, we show how receiver-function-like signals can show high sensitivity to magma bodies that are comparable in size to their 5-10 km wavelengths. We document such signals at most high-threat volcanoes in the Cascades, showing consistent estimates of depths to the shallow magma system for at least six volcanoes. These images place some bounds on the amount of magma present and require that much of the magma systems persist at shallow depths for the life of the volcanoes. This approach shows for the first time consistent imaging of volcanoes along an entire arc.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Deploying a large nodal array for high-resolution imaging and seismicity analysis of Kīlauea Volcanic System

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In summer 2024, 340 three-component SmartSolo IGU-16 3C 5Hz nodal seismometers were deployed at 116 sites in the East Rift Zone (ERZ) of Kīlauea volcano, on the Island of Hawaiʻi. To address the nodes' battery life limitation of approximately 30 days, three instruments were co-located at each site, allowing for three months of continuous recording. The array is designed to push developments in high-resolution mantle-to-crust seismic imaging, temporal monitoring, seismicity characterization, and fault loading response caused by ascending magma in the ERZ. As the current model of Kīlauea's structure has been altered by the 2018 and 2020 eruptions, key questions pertaining to Kīlauea's new eruptive phase and transport pathways remain still unanswered. During the array's recording period, three magma intrusions accompanied by swarm seismicity and deformation were observed, culminating in an eruption near the Nāpau Crater in the Middle East Rift Zone in September 2024. These events provide compelling evidence that magma has begun re-entering the ERZ after years of absence. Here we provide an overview of the deployment, evaluate the quality of the collected data, and explore the dataset's potential for seismic imaging. We also show first results, including the development of an initial seismicity catalog using state-of-the-art machine learning techniques, to be used in future velocity inversion analyses. The 2-D nodal array offers new, independent constraints that complement previous geophysical investigations, such as magnetotelluric surveys conducted in the same region. Together, these datasets will provide a more comprehensive, system-wide understanding of Kīlauea's magmatic system and its evolving structure.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Conditions for complex or simple flow during magma ascent: Insights from 3D laser imaging of analogue dykes

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It is widely recognized that the physical, chemical and thermal properties of magma strongly impact how explosive a volcanic eruption will be and how long it will last. However, how these are controlled by the ascent dynamics of dyking is relatively understudied. Magma flow in dykes is often assumed to be simple and unidirectional, however geological evidence of magma flow recorded in fossil dykes often suggests complex multidirectional flow patterns have occurred. Existing dyke models are insufficient to explain their emplacement and need to account for magma flow which varies across the dyke breadth and thickness over time as the dyke ascends through the crust. We conducted dynamically scaled analogue dyke experiments using a laser-based stereoscopic imaging system to measure three-dimensional (3D) flow dynamics inside flux-driven fractures for the first time. An elastic, transparent host medium (gelatine) was intruded by either a simple Newtonian fluid (a glycerol solution or salt water) or more complex shear-thinning fluid (a xanthan gum-salt water solution) to represent magma with variable proportions of melt, crystals and bubbles. Our results show that the Newtonian magma model exhibits complex and strong 3D effects, whereas the shear-thinning magma model produces simple, 2D unidirectional flow. This challenges major assumptions of most numerical and conceptual models of magma ascent, impacting the dynamics of magma connections between deep crustal reservoirs and the dynamics of shallow feeder dykes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Using volcanic tremor to ellucidate magmatic systems

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Seismology has been at the forefront of monitoring volcanoes and imaging magmatic systems at depth; yet one seismic signal remains particularly elusive: volcanic tremor. It is difficult to locate due to a lack of clear onsets and can last between minutes to years. Global comparisons are lacking, as this signal varies from volcano to volcano in duration, frequency content, recurrence interval and depth estimate (if at all available) and relationship to other observables such as gas emission, deformation and eruptive activity. Hence, there are no clear links between the observations and the many invoked potential source models. Using seismic data from Oldoinyo Lengai (Tanzania), Taiogaite (La Palma, Spain), Pahala (Hawaii, USA), and Ruapehu (New Zealand), we present a comparative study on tremor properties and locations, discuss what they can tell us about magmatic processes and present new findings on how melt viscosity plays a crucial role in tremor amplitude. We use these observations to elucidate magmatic plumbing systems across the crust and overturn decade-long debates on the proposed shallow nature of tremor. We suggest that tremor holds the key to understanding yet unresolved problems regarding the structure and dynamics of magmatic plumbing systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Magma intrusion at Askja Caldera, Iceland, between 2021 and 2023 constrained by modelling of microgravity and deformation data

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We present results indicating that the uplift at Askja observed from 2022 to 2023 is consistent with the intrusion of magma into a sub-volcanic reservoir at 2.8 km depth. Askja, a volcano in the Northeast of Iceland, hosts three calderas, with the youngest having been formed during the 1875-1876 rift event. The last eruption was a Hawaiian-style event that occurred in 1961. Since then, Askja has been monitored using levelling, GNSS and InSAR, showing alternating periods of subsidence and uplift. After decades of subsidence, an uplift was observed in July 2021 at an initial rate of ~700 mm/yr, decreasing to ~350 mm/yr, briefly halting in 2023 and resuming in April 2024. Recent studies have concluded that a new intrusion of magma causes this uplift. Here, we test the nature of the intrusion and the origin of the magma. Microgravity data collected in 2022 and 2023 indicate a mass increase of $9.2*10^{12}$ kg beneath the volcano during this period. Joint modelling of the microgravity and the deformation data, assuming an ellipsoidal intrusion into elastic crust, gives a mass intrusion density of 2350 ± 550 kg/m^3, corresponding to a basaltic magma. To understand the influence of a non-elastic regime on the modelled microgravity and deformation, we have built a finite element model that consists of a melt reservoir surrounded by a poroelastic mush. We explore a realistic range of parameters for this model and compare them to the surface data.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Magmatic Structure and Melt Storage beneath the Katmai Volcanic Group, Alaska

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The Katmai volcanic group (KVG) within the Alaskan Aleutian arc is an unusually dense group of active volcanic centres (Mounts Martin, Mageik, Trident, Katmai, Griggs, Snowy, and Novarupta). The KVG was the locus of the largest eruption of the 20th century. During the 1912 eruption, rhyolite was erupted from a new vent (Novarupta) contemporaneous with collapse of Mount Katmai (10 km away). A hydraulic connection has been hypothesized between the two vents based on the above observation and on a small volume of andesitic magma with the geochemical signature of Mount Katmai that erupted from Novarupta at the onset of the eruption. Unanswered questions about the structure and dynamics of the KVG include the origin and storage zone for the 1912 erupted rhyolite, its connection (if any) to the dense group of andesitic stratovolcanoes surrounding the Novarupta vent, the cause for off-arc centres such as Mount Griggs, and the reason for enhanced magmatic flux beneath the KVG relative to other segments of the arc. Our recent wideband (1 kHz – 1 mHz) magnetotelluric survey of the region encompasses the Katmai group of volcanoes (110 sites) and is bisected by an arc-perpendicular profile crossing the Alaska Peninsula (18 sites) spanning subducting slab depths of 60-200 km. Coast effects are present in the magnetotelluric data; however, qualitative analysis of the data indicates the Jurassic sedimentary section upon which the arc is built, the highly resistive arc itself, and a swath of elevated conductivity beneath the arc axis that likely reflects melt storage.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

One small step in the crust, one giant leap for magma: Insights into magma differentiation from basalt to rhyolite at Cordón Caulle derived from rhyolite-MELTS simulations

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Magma mush systems are commonly invoked as the source from which crystal-melt segregation produces rhyolites, but these systems are rarely observed. The 2011-2012 VEI 4 eruption of Cordón Caulle produced rhyolite lavas which scavenged basaltic enclaves containing interstitial glass similar to their host rhyolitic lava. These enclaves offer a window into an active, shallow basaltic mush system. This mush was previously proposed as the source from which crystallization generates high-silica rhyolite in a single step. Here, we use rhyolite-MELTS to determine whether this is thermodynamically realistic. First, we use melt geobarometry to establish that enclave-derived pressures (~25-200 MPa) are consistent with those previously determined for the lavas. We then simulate isobaric crystallization using a range of initial starting water concentrations. We find that, using an initial melt matching the whole-rock composition of the enclave, it is possible to produce via fractional crystallization a rhyolite that matches the composition of the natural enclave glass. We also explore the physical consequences of crystallization and fluid exsolution during magma evolution. Lower initial water simulations (0.5-1.0 wt.% H_2O), at pressures of 100-200 MPa produce changes in volume most consistent with pre-eruptive ground deformation signals. We determine the timescales of heat loss from the crystallizing basaltic magma to be ~8-25 ka, but it is plausible that heat loss occurred in <5 ka, which is broadly consistent with repose times of the system. The application of rhyolite-MELTS to an actively monitored system offers multifaceted insights into the geochemical, thermal, and physical evolution of magmas.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Barometers Behaving Badlier: How well does resolve transcrustal magma systems?

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Volcanoes are underlain by magma transport and storage systems of transcrustal extent, and the nature of these systems strongly influence key parameters such as eruption rates, styles, and volumes, and erupted compositions. Petrological methods are widely used to infer the nature of crustal magma systems, but techniques that estimate pressure – essential for establishing the geometry of magmatic systems – are limited by uncertainties, and by methodological and sampling biases. Recent work shows that the uncertainties associated with common barometry techniques (± 1 standard error) are relatively large: 5-8 km for mineral and mineral-liquid equilibria, and ~20% for fluid and melt inclusions. We have developed a probabilistic forward modelling approach to study the efficacy of petrological techniques for resolving the geometry of crustal magma systems. To do this we generate a synthetic mineral population based on a defined magma system geometry, and estimated probabilities for mineral formation, survival, and sampling. The synthetic population is then bootstrap resampled to simulate natural data sets, and results are dispersed to reflect uncertainties. Results show that while the larger scale features of crustal magmatic systems can generally be resolved, finer structure – including that needed to test conceptual models – are not resolvable. Small data sets ($n < 50$) also mean that reproducibility is poor, and may produce false positives and continuous PT "pseudoarrays" from discrete magma storage regions. The latter closely resemble arrays in the literature which are commonly interpreted to represent broadly continuous or transcrustal distributions of magma within the crust.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

3D Seismic attenuation structure La Palma (Spain): unraveling the volcanic plumbing system of the Canary Islands

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Tomographic images based on seismic velocity and attenuation are some of the most powerful tools for investigating volcanic complex structures and behaviors. Several techniques can be used to obtain these images, each revealing different physical properties of the medium and each having different resolution limits. Although these models aim to associate physical properties with geological structures, in most cases, individual images can only partially reveal the subsurface volcanic system, which limits interpretations and introduces uncertainties. In order to illuminate the plumbing system and to explain the diversity of the eruptive processes observed in the Canarian archipelago, we analyzed the seismic data during the 2021 La Palma eruption to obtain a high-resolution seismic attenuation tomography and to joint interpret the new results with previously obtained tomographic models. We analyzed the same database that D'Auria et al., (2022) used in the velocity tomography and we obtained a new tomographic model of La Palma. The new images confirm the existence of an intermediate chamber. We have also identified a shallow high attenuation region that could be related to a hydrothermal alteration beneath the Cumbre Vieja volcanic complex (D'Auria et al., 2022; Cabrera-Pérez et al., 2024). Our results highlight the structural complexity of La Palma and they reveal that volcanic systems are not comprised of well-defined units with distinct physical properties; rather, they represent complex and dynamic structural units that evolve along with magmatic processes. Being able to delimit these heterogeneities is essential to understanding the future kinematics and dynamics of the Canarian archipelago.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

CO2 gas content measured in the 2024 Svartsengi, Iceland eruptions used to elucidate magma storage conditions

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The 2023-2024 eruptions within the Svartsengi volcanic system, Iceland are likely sourced by a series of sill-type magma bodies which reside within an extensive magma domain. These magma pockets are effectively modeled as a deflating Mogi source during each event to derive the optimal depth of the magma body that fails at the onset of each dike intrusion/eruption. CO_2 is readily degassed from silicate melts at greater depths than other more soluble major volcanic gases. A diminishment of CO_2 relative to H_2O and SO_2 measured in the gases released in the first stages of an eruption, in comparison with an expected initial composition, helps to reveal the pre-eruptive conditions of the magma. CO_2 loss prior to eruption is a function of the storage depth of the individual magma pockets as CO_2 solubility is strongly pressure dependent as well as the time available for segregation and loss. The time prior to an eruption allows the magma in the storage region to degas its insoluble CO_2, while at the same time, fresher magma flowing in from a deeper source that contains close to the original CO_2 content is mixing in. We present here a series of FTIR measurements of gases released early in these eruptions. In combination with the results of geodetic modeling, we use the CO_2 content of the gasses to learn more about the contribution of outgassed CO_2 to the measured deformation signal as well as the rate of CO_2 loss in the magma storage region prior to each eruption.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Magma accumulation and asymmetric ring-fault activity preceding the 2024 eruption of Fernandina volcano, Galápagos Islands

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At caldera volcanoes, ring faults can play a key role in controlling the dynamics of eruptions and patterns of associated deformation and seismicity. However, we have less understanding as to how these structures can influence the nature of eruption precursors and shape the process of eruption initiation. Here we show that the March 2024 eruption of Fernandina, a frequently-active basaltic caldera volcano in the Galápagos Islands, Ecuador, was preceded by a 2.5-year episode of magma accumulation, driving surface uplift and asymmetric seismicity on a ring fault system. Analyses of data from a local hybrid seismic network-array, and satellite-derived deformation measurements, reveal: (1) that rates of volcano-tectonic earthquakes at Fernandina increased progressively with surface uplift from November 2021 until the end of April 2023; (2) the subsequent ten months of unrest involved a sequence of short-duration uplift and seismicity pulses; and (3) a final unrest pulse, starting in late February 2024, included a Ml 4.4 earthquake on 2nd March, followed 20 hours later by the initiation of an intense, laterally-migrating seismic swarm. This swarm culminated after two hours with the onset of the eruption on a set of fissures on the SE caldera rim. Earthquake source locations suggested asymmetric activity of the ring fault system at depths of 4–6 km, between shallow and intermediate-depth inflation sources. These observations suggest a complex interplay between the magmatic plumbing and ring fault systems at Fernandina and reveal important differences in behavior with previous eruptions at Fernandina and elsewhere in the Galápagos.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

The anatomy of a magmatic system, revealed by multi-disciplinary seismological methods in central Costa Rica

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We deployed a temporary network composed of 20 seismic stations, saturated with a further 46-permanent Costa Rica (OVSICORI and RSN) network, from April 2018 to May 2019. We obtained a database of 967-local-earthquakes, producing an optimised local 1D-velocity-model to more precisely locate events. Clustering and alignments of seismicity obtained with HypoDD were interpreted as diverse interactions between locally-driven fluid-flow in ductile magmatic zones, and brittle deformation within the volcanic system. Intersecting right-and-left-lateral strike-slip regimes dominated local-scale deformation. These two primary motions are linked to the opposing regional-scale tectonic escape of the forearc sliver, and Panama microplate rotation. We observe that Irazú and Turrialba volcanoes are influenced sub-independently, as seismicity associated with each volcano related to geographic proximity to regional-scale tectonic influences. By focusing on low-frequency seismic noise, we constrained a 3D-shear-velocity model using Ambient Noise Tomography (ANT). This revealed multiple low-velocity anomalies, interpreted as an intermediate depth common magmatic reservoir feeding two shallower magmatic/hydrothermal systems. We also derived a travel-time, local-scale tomography using LOTOS from the relocated earthquake catalogue. The Local Earthquake Tomography (LET) revealed contrasting low and high Vp/Vs ratio anomalies at intermediate crustal depths beneath the volcanoes, suggesting two separately operating magmatic reservoirs, within a larger, shared ductile region. Both intermediate-depth reservoirs showed evidence of feeding from a deeper magmatic source, and also connectivity to the surface through shallow systems of upward-fluid-migration. The combination of earthquake relocation, ambient-noise and local-earthquake tomography produced comprehensive agreement between three established passive-seismic methods, linking seismicity, neotectonics and volcanism at regional- and local-scales.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Advances in the search of an ambient noise tomography model of La Palma Island after the 2021 eruption

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We study continuous seismic ambient noise recorded by a temporary dense network in La Palma (Canary Islands, Spain) to develop high-resolution velocity models of the uppermost crust. After the 2021 Tajogaite eruption, the IMAGMASEIS project established several dense seismic arrays on the island to enhance our knowledge of its shallow velocity structure. One of these networks includes 37 broadband seismometers provided by GFZ and the University of Granada, alongside 21 permanent stations operated by the Spanish National Geographic Institute (IGN) and the Volcanological Institute of the Canary Islands (INVOLCAN). This network ensures dense coverage of the entire island, with inter-station distances averaging 5 km and a maximum separation of 40 km. Data collection started in September 2023 and ended in October 2024. To estimate Green's functions between station pairs, we stacked cross-correlations of 1-day windows in the time domain over the recording period. We also examined the impact of various preprocessing steps, including spectral whitening and time normalization. Rayleigh-wave dispersion curves were extracted using frequency-time analysis (FTAN), obtaining robust results in the 1 s to 6–7 s period range. Our preliminary findings agree with previous studies, revealing high relative group velocities in the geologically older northern region and lower velocities in the southern area, characterized by historical volcanic activity. These results will be used to perform an inversion and obtain a tomographic model of the island.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Lower-to-mid crustal magma dynamics revealed by in-depth analyses of Sr and Nd isotope time-series of basalt erupted 2021-2024 on the Reykjanes Peninsula, Iceland.

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Seven short-lived basaltic fissure eruptions took place from December 2023 to December 2024 at the Sundhnúkur crater-row on the Svartsengi intra-transform spreading centre. The duration and magma volume of each eruption generally increased with time until the last event. The whole-rock major-element composition of the basalt produced is limited (with 7-8.5% MgO) whereas incompatible element and Sr-Nd isotope ratios vary (e.g. $^{87}Sr/^{86}Sr$: 0.70312 - 0.70323 and $^{143}Nd/^{144}Nd$: 0.51302-0.51295) irregularly with time (Matthews et al. 2024) until June 2024. Similar variability was observed for the isotope ratios during the six-months long 2021 eruption at Fagradalsfjall ($^{87}Sr/^{86}Sr$: 0.70310 - 0.70323 and $^{143}Nd/^{144}Nd$: 0.51302-0.51295); Halldórsson et al., 2022; Marshall et al. 2024). An important difference is that the Sr isotope ratios are significantly higher for a given Nd isotope ratio in the 2024 Sundhnúkur basalt. Mass-balance criteria exclude significant crustal interaction and consequently, the two eruptions are fed from different deep-seated magma aggregation zones. The eruptions at Sundhnúkur crater-row all start as an intense but short-lived phase on several km long fissures reflecting pressure release in a magma chamber and consequent deflation. After June 2024, the Sr- and Nd isotope ratios and the incompatible element ratios reached the background values of the historical basalt lavas on the Reykjanes Peninsula. Therefore, the evacuation of the “enriched” (high $^{87}Sr/^{86}Sr$ and K_2O/TiO_2) basalt compositions, erupted from late April 2021, through 2022 and July 2023 in the Fagradalsfjall region and from December 2023 to June 2024 at Sundhnúkur, from the trans crustal magma domain may be over.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Volcano-Tectonic Coupling at the Christiana-Santorini-Kolumbo Volcanic Arc

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Silicic volcanic systems are observed globally in areas of local extensional or transtensional stress, especially in continental rift zones and back-arc regions. However, the role of crustal faults in magma migration remains poorly understood. The Christiana-Santorini-Kolumbo volcanic field, located in the South Aegean Volcanic Arc, offers the opportunity to investigate the interplay between volcanism and tectonism in a continental rift zone. Integrating high-resolution seismic reflection data with deep-earth sampling from IODP Expedition 398, we unravel a coupling mechanism between crustal faulting and explosive volcanism in this region. Our findings reveal a major NE-SW-striking normal fault parallel to the Kolumbo Volcanic Chain (KVC), defining a tectonic half-graben structure. This fault, previously considered to exhibit limited vertical offset, shows a displacement exceeding 200 m based on tephra and biostratigraphic markers recovered from cores. The volcanic edifices of the KVC are situated approximately 6 km from the surface trace of this fault on its hanging wall. Adjacent non-volcanic rift basins display pervasive internal faulting at comparable distances from basin-bounding faults, implying that these zones of localized extension provide preferential pathways for magma ascent. P-wave tomography data suggest that the tectonic graben system hosting

the KVC may extend beneath Santorini, explaining the linear orientation of volcanic features at Santorini and the KVC. We show that the listric Kolumbo Fault may intersect Kolumbo Volcano's mid-crustal magma reservoir, facilitating melt migration through fault-induced shearing. Our study implies a critical influence of normal faulting on magma migration and emplacement in extensional back-arc systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

2023-2025 inflation episodes within the Svartsengi Volcanic System, SW Iceland: Implications for improved forecasting and hazard assessment

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Since October 2023 the Svartsengi volcanic system (SW Iceland) has experienced ten inflation episodes associated with magma inflow into a ~4–5 km-deep magma domain. Inflation episodes occurring between October 2023 to November 2024 were interrupted by rapid deflation and concurrent dike intrusions, leading to a total of 7 eruptions within the nearby Sundhnúkur crater row and its extension. From October 2023 to March 2024, inflation was detected by GNSS and InSAR observations in-between the diking events/eruptions. However, since the 16 March 2024 dike intrusion, inflation resumed soon after the onset of eruption, despite the on-going extrusion of lava flows. This study focuses particularly on the inflation events to strenghen our understanding of the magma supply and evolution of the magmatic system following each diking event/eruption. We jointly modelled the GNSS and INSAR observations by using a variety of source geometries (e.g., spherical, sill-type and ellipsoidal sources) embedded in a homogeneous, elastic half-space. Interestingly, geodetic models infer a variation in depth of the in-between dike inflation and co-diking deflation, possibly indicating the involvement of multiple magma pockets as suggested by the geochemical compositional variability of the erupted material. Enhanced comprehension of the magmatic plumbing system, its evolution and dynamics that led to the sequence of repeated dike intrusions and eruptions observed at Svartsengi may assist in improving (i) the real-time monitoring by tracking early precursory signals of withdrawal of magma from the magma domain towards the surface, (ii) eruptive dynamics and thus, (iii) volcanic hazard associated with it.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

A Voluminous Melt-rich Magmatic Reservoir Beneath Mayotte Island

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The exact nature of crustal magmatic reservoirs is elusive since they cannot be sampled in situ. The traditional view that magma chambers contain essentially molten material has recently been replaced by the transcrustal magmatic system (TCMS), in which reservoirs are mostly composed of immobile magmatic crystals with a minute fraction of more mobile melt, creating a "magmatic mush". Eruptions are possible if a significant portion of melt segregates into melt lenses within the mush reservoirs. The TCMS concept is however a default model essentially justified by the absence of clear geophysical signatures of melt-rich magma chambers, and by the rare and tentative estimates of the melt fraction in the crustal storage zones based on geochemical and textural analysis of eruptive products. Here, we image a bright electrical conductor at 23±1 km b.s.l. beneath Mayotte island that we interpret as a magmatic reservoir, based on laboratory measurements of Mayotte's melt conductivity. This large magmatic reservoir (> 200 km^3) contains a high melt fraction (22-42%). Such a crystal to liquid ratio matches the reconstructed differentiation paths conducive to the basanite to phonolite melts that recently erupted at Mayotte. This reservoir is possibly connected to the system that fed the large submarine eruption of Fani Maoré in 2018-2019.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Alkaline magma generation and differentiation between proximal ocean island shield volcanoes: Insights from the Karthala and La Grille plumbing system(s), Grande Comore

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Alkaline volcanism within ocean islands has long been associated with melts derived from a metasomatised mantle. Trace element ratios record compositional attributes of the mantle and preferentially melted metasomatised veins. The island of Grande Comore hosts La Grille and Karthala, two proximal, active alkaline volcanoes with differences in source characteristics, whole rock composition, and eruption styles. Metasomatic veins have been reported within xenoliths of La Grille lavas in addition to modal metasomatism of the mantle source inferred from trace elements. In contrast, Karthala's primitive lavas show only minor input from a modally metasomatised mantle. This study employs major and trace elements, Sr-Nd isotopes, and single mineral chemistry to elucidate the plumbing system by characterising the formation and differentiation of the alkaline products from the two volcanoes. Initial findings identify a new, third primitive magma series within Grande Comore, distinguishable by SiO_2, HFSEs, and LREEs. Preliminary trace element modelling of La, Dy, and Yb in mantle residues, negative anomalies of K, and normalised incompatible element patterns characterised by HREE depletion indicate the influence of a metasomatised, garnet-bearing lherzolite-derived melt as at least one component for each primitive magma series. XRD analyses of aphanitic tephras trace the unique mineral assemblages that are associated with these distinct magma series, further defining the evolution of these compositional suites. These preliminary findings, in conjunction with single mineral chemistry of clinopyroxenes and clinopyroxene-based barometry, will detail the plumbing system beneath Grande Comore and provide new insights into small-scale mantle heterogeneities beneath ocean islands.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Imaging magma transfer during the 2021 Tajogaite eruption (La Palma, Canary Islands) using distributed acoustic sensing.

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Distributed Acoustic Sensing (DAS) has been demonstrated to be a valuable tool in different seismological applications. Until now, the focus has been on earthquake detection, location, and subsurface imaging. Here, we present an application of DAS for imaging deep seismo-volcanic sources that were active on Cumbre Volcano (La Palma, Canary Islands) during the 2021 Tajogaite eruption, which lasted rom Sep. 19th until Dec. 13th of 2021. On Oct. 19th we deployed the fiber optics cable which begins about 10 km east of the eruptive vent, and reaches distances of up to 50 km. The DAS recordings of the volcanic tremor revealed a complex wavefield mainly consisting of surface waves. The array analysis shows that, apart from the ballistic arrivals of surface waves radiated by the eruptive vents, the wavefield contains arrivals related to the scattering from topographic features of the island and its surroundings. Furthermore, it revealed that, apart from surface waves, the wavefield contains arrivals compatible with body waves radiated by deeper sources. We interpret these sources as the effect of the volcanic tremor generated by the flow of magma within the system of feeder dikes. Using DAS with our analysis technique allowed us to characterise the spatio-temporal evolution of the seismic activity along the feeding system. We discuss its relationship with other geophysical, geochemical, and petrological parameters and its implications for a better definition of the eruptive mechanism.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.5: Illuminating Active Volcanic Plumbing Systems

Allocated presentation: Poster

Subsurface Crustal Structure of Kanlaon Volcano, Philippines from 3D Tomography

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Kanlaon Volcano on Negros Island in central Philippines is one of the country's most active volcanoes, with an eruptive history documented since 1866. Over 30 eruptions, primarily phreatic in nature, have been recorded. To gain a better understanding of Kanlaon's subsurface crustal system and the factors influencing its activity, this study conducted the first 3D seismic tomography study of the volcano. The 3D P- and S-velocity models were produced using the free Local Earthquake Tomography (LOTOS) software (Koulakov, 2009) for iterative passive source tomography. Utilizing data from 16 seismic stations of the Kanlaon Volcano Network and nearby stations of the Philippine Seismic Network, the dataset covered a wide range of earthquake depths from May 2017 to November 2024. This allowed the generation of high-quality, topography-corrected volcanic earthquake relocations and to image the volcano's subsurface structure at higher resolution. The observation period includes stages of seismic unrest: the detection of deep long-period (DLP) events in 2017 and VT swarms in June 2020 and September 2024. Preliminary results reveal distinct seismic velocity distributions (Vp and Vs) and Vp/Vs ratios, providing valuable imaging of Kanlaon's magmatic plumbing system. **Keywords**: Kanlaon Volcano, 3D seismic tomography, magmatic plumbing system

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Talk [Invited]

The contribution of petrological monitoring during recent eruptive crises of Mt. Etna, Italy

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Mt. Etna is one of the most active basaltic volcanoes in the world and one of the best monitored, namely by the Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo (INGV-OE), with instrumental networks, field surveys and laboratory analyses. In particular, the petrological monitoring has been carried out since the 1990's, and with the enhancement of its organization over time, today enables following the evolution of volcanic crises that may be potentially dangerous for the local population. Firstly, the contribution illustrates the organization of petrological monitoring at INGV-OE during an on-going eruption (syn-eruptive monitoring). The procedure consists of different steps, which involve an expert staff tasked with the sampling, archiving of collected materials, preparation of the samples, laboratory analyses and data interpretation. Results, which are integrated with information from other monitoring disciplines, are focused to rapidly detect the preliminary characteristics of magmatic processes driving the eruptive activity and to infer the possible temporal evolution of the on-going phenomena. Detailed aspects of pre-eruptive and eruptive processes can be investigated with more extended petrological studies, which require additional time and expertize. The second part of the contribution focuses on the results of petrological monitoring applied to the high-frequency 2020-2022 lava fountains of the South-East Crater (Mt. Etna). Finally, the procedures of petrological monitoring are critically discussed to identify strengths and weaknesses in evaluating the evolution of volcanic phenomena, in order to provide reliable scientific information to support the decision-makers responsible for managing volcanic crises.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Talk

Overview of recent Hawaiian eruptions (2023–present)

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This presentation covers the numerous eruptions and shallow intrusions in Hawaii between the 2023 and 2025 IAVCEI Scientific Assemblies. At the time of writing (December 2024), all activity has occurred at Kīlauea volcano, with six eruptions and several intrusive episodes, all confined within Hawai'i Volcanoes National Park. Although these episodes have caused no threat to life, intrusions and ground deformation damaged a key road and fissures and associated lava flows destroyed part of a backcountry trail and a campground. What is remarkable about activity since early 2023 is its geographic diversity. The first two eruptions (January–March 2023, June 2023) occurred in the same location as previous Kīlauea post-2018 caldera collapse eruptions: in Halema'uma'u, within Kaluapele (Kīlauea's summit caldera). The September 2023 eruption started in Halema'uma'u but then propagated eastward, albeit remaining within Kaluapele. The next two eruptions left Kaluapele altogether, with a 10-hour long Southwest Rift Zone (SWRZ) eruption in June 2024, and an approximately 5-day upper/middle East Rift Zone (ERZ) eruption in September 2024. Both eruptions were preceded by intrusive activity and widespread seismicity: an intrusion in the upper SWRZ in January 2024 caused ground cracking, and intrusive activity in the upper ERZ damaged a main national park road. Eruptive activity returned to Halema'uma'u in December 2024. The U.S. Geological Survey's Hawaiian Volcano Observatory has used this period of frequent and diverse activity to improve our monitoring network, test and practice new methods, and continue engagement with our many partners and communities.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Talk

Spinel crystals in tephras preserve heating and cooling pathways during magma ascent and eruption at La Palma, Canary Islands

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Particles ejected from Strombolian jets can be glassy to microcrystalline in texture, can vary as particles recycle within jets, and preserve insight to the conditions of shallow magma ascent and eruption. We focus our study on the composition of spinel crystals (EPMA) in daily-constrained airfall samples from the 2021 Tajogaite eruption, La Palma, Canary Islands, with an aim to constrain conditions of magma ascent and jetting. Applying a Mg-in-magnetite thermometer [1], we observe a wider variation in crystallization temperatures of spinel rims as the eruption progresses. This variability could reflect more diverse fountaining dynamics that followed a major cone collapse in the first week of the eruption. Spinel crystals in glassy (primary juvenile) ash particles record the narrowest range in temperatures (942°C±23°C) and are dominantly unzoned. The lowest (875°C) and highest (976°C) temperatures are recorded in spinel crystals in microcrystalline (recycled juvenile) ash particles. We interpret reverse and normal chemical zones (8-20 μm) across single-crystal traverses to represent pathways of heating and cooling, respectively; however, deciphering where crystallization takes place is a challenge. Crystal growth can occur at depth, during ascent, or at the surface in the hot jets. We argue that the Mg-in-magnetite thermometer may be a useful petrologic tool for estimating temperature conditions beneath and within Strombolian jets and, with continued textural work, may yield important insight for how conduit and jet dynamics produce tephra particles of different morphologies and how these processes may vary over the duration of an eruption. [1] Canil and Lacourse (2020), *Chemical Geology*

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Talk

The 2021-23 Fagradalsfjall and 2023-? Sundhnúkur Fires, Reykjanes Peninsula, Iceland

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In the early morning on 19 March 2021, when an eruption began on a 180-m-long linear vent system at the Fagradalsfjall volcanic complex, the Reykjanes Peninsula, Iceland, entered into its 4th Eruption Period in the last 4000 yrs after 781 years of quiescence. This also marks the onset of the 2021-23 Fagradalsfjall Fires, featuring 3 effusive eruptions: the 19.03-18.09.2021 Geldingadalir, 03-21.08.2022 Meradalir, and 10.07-05.08.2023 Stóri-Hrútur events. Collectively they erupted 135*$10^6 m^3$ (DRE) of olivine tholeiite lava (8-8.5wt% MgO) that was extracted from a ~553 km magma storage zone situated at 9-12 km depth beneath Fagradalsfjall and containing an estimated ~15-25 km^3 of melt. Late in 2023 the unrest shifted from the Fagradalsfjall volcanic lineament and onto the Sundhnúkur volcanic lineament that stretches across the Reykjanes Peninsula between the towns of Grindavík and Vogar. To date (i.e. January 2025) the 2023-ongoing Sundhnúkur Fires have featured 7 effusive eruptions. Collectively, they have produced ~170*10^6 m^3 (DRE) of olivine tholeiite lava (6.0-6.8wt% MgO) erupted from a 41.50.004 km magma storage situated at ~5 km depth beneath Svartsengi. This storage is supplied by the Fagradalsfjall magma storage described above. An intriguing aspect of the Sundhnúkur data set is that in the first 3 events the volume of magma accumulated in the Svartsengi magma storage prior to eruption was roughly equal to volume of erupted lava. In the 4 events that followed the volume of erupted lava is factor 1.5-2 greater than the accumulated magma volume, indicating direct additional contribution from the deeper Fagradalsfjall magma storage.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

A geomorphological analysis of the 2021–2023 Fagradalsfjall eruption series

Madison Tuohy*[1,2], Christopher W. Hamilton[2], Brett Carr[2], Birgir Vilhelm Óskarsson[3], Joana Voigt[4], Ármann Höskuldsson[5,6], William Michael Moreland[7,] Ingibjorg Jonsdottir [5,8] Þorvaldur Þórðarson[8]

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Following a period of intense precursory activity, an eruption at Fagradalsfjall (Iceland) began on 19 March 2021. This eruption lasted six months, ending on 18 September 2021. A second eruption occurred 3–21 August 2022, and a third from 10 July to 5 August 2023. During these eruptions, we conducted numerous unoccupied aircraft system (UAS) flights, collecting high-resolution survey data for the active lava flows and resulting deposits. The UAS data provided exceptional spatial (cm-scale) and temporal resolution, enabling detailed analysis of lava emplacement dynamics, including channel flow and subsequent emplacement patterns through time-series digital elevation models (DEMs), orthomosaics, and videography. These data, combined with airplane surveys from Loftmyndir and the Icelandic Institute of Natural History, were used to generate high-resolution (1:600-scale) facies maps of the flow-field from multiple time steps for each eruption. These maps and subsequent analyses reveal the dynamic emplacement of basaltic lava flow-fields, shaped by complex topography, interactions with previously emplaced lava, and varying rheological behavior due to changes in cooling rate as open channels transitioned into thermally insulated internal pathways. Observations show that both ’a’ā and pāhoehoe lava types were common, but were typically associated with more complex “transitional” rubbly and spiny pāhoehoe units. The time-series of facies maps help to inform: (1) changes between cooling-limited and volume-limited emplacement styles in response to lava pathway evolution; and (2) the effects of surface disruption and lava cooling rate during “fill and spill” events that are characterized by sudden transitions in local effusion rate.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

From Lava to Life: Microbial Colonization in Volcanic Environments

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How do uninhabited environments become colonized by life? To explore this question, we studied the microbial colonization of newly emplaced lava flows from the 2021–2023 Fagradalsfjall eruptions in Iceland. We collected samples from newly cooled lava, some solidified only hours before collection, and tracked how microbial communities developed over three years. During the first six months of the 2021 eruption, we sampled biweekly at fixed sites, continuing with periodic collections afterward. When the volcano erupted again in 2022 and 2023, we sampled fresh lava from these events, creating a unique dataset that spans three eruptions. The data enabled us to quantify how microbial life consistently established itself after volcanic activity. Our analyses show a two-step process. First, random vectors of colonization brought extremotolerant microbes to the lava, followed by community stabilization over time. Using machine learning models trained on the 2021 data, we accurately predicted microbial community patterns for the 2022 and 2023 eruptions, demonstrating that ecological succession in these volcanic environments is dynamic and predictable. This research highlights how life can emerge and stabilize in new lava flows, shedding light on the processes that may have occurred on early Earth and could occur on other volcanically active planets. By understanding microbial colonization in harsh environments, we also gain insights into the resilience and adaptability of life in the face of environmental challenges.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

Continuous sampling and investigation of volcanic ash to monitor eruption sequence at andesitic volcanoes in Japan

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We carried out time-series sampling of ash fall at Sakurajima, Shinmoe-dake, and Suwanosejima volcano, southern Japan, to understand the mechanism of eruption sequence. At Sakurajima volcano, we collected daily samples for more than 10 years of vulcanian activity by an automatic apparatus. We also constructed systematics of volcanic ash by optical spectroscopy to elucidate how the mixtures of ash particles with different characteristics are generated and to compare with other observations such as seismicity, ground deformation, etc. Ash samples consist of several types of particles with different sizes that make a quasi-linear trend in color space, and drastic changes in eruption sequence have been recognized by monitoring these data variation, trend, and endmembers. At Shinmoe-dake, Kirishima volcano, we succeeded in collecting time-series samples during the waxing period of 2017-2018 eruption. Some spectroscopic methods are executed for different size fractions to elucidate that color of bulk ash samples changed systematically with eruption transitions whereas fine and coarse fractions have different colors that changed with time. These changes are interpreted to reflect appearance/disappearance of different particle types that changed with eruption style. Visible microspectroscopy was useful in quantifying color of single ash particles to classify objectively and to derive the componentry automatically. At Suwanosejima volcano, we carried out componentry and glass chemical analyses of two hundred years of ash layers in time-series in detail and found that the activation of eruptions is often preceded by mafic injections of short interval followed by crystallization at shallow depths resulting in alternative phenomena of eruptions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

Determining the mantle δ18O signature of the 1730-1736 Timanfaya eruption, Lanzarote

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The ca. 1730-1736 volcanism on Lanzarote is a matter of contention as some authors argue that the volcanic activity contradicts the hot spot model for the Canary archipelago. In addition, the compositional changes in the eruption sequence led to discussion on whether mantle source processes or crustal influences are the controlling factors for the observed compositional variability. Here we present 34 new $\delta^{18}O$ values, coupled with new major and trace element data, from the second half of the Timanfaya eruption (ca. 1733-1736) to determine if crustal assimilation can be detected and to establish if primitive compositions display a MORB or a plume-type signature. Our results show a range of +4.87 to +5.65‰ (± 0.12; 2 sigma) for sampled lavas, whereas crustal xenoliths range from -9.52 to +23.74‰. The more evolved samples, in turn, show mildly elevated $\delta^{18}O$ values, implying that crustal input occurred, but was localised and volumetrically limited (≤ 5 %). The most primitive samples in the collected lava suite yield values of ~ +4.9‰ and the combined lava samples average to ~ +5.3‰, thus providing a primary mantle derived magmatic range of +4.9 to +5.3‰. The most primitive values of the sampled lava suite are thus inconsistent with a pure upper mantle derivation (MORB= +5.5 to +5.7‰), but require a plume-type mantle input, implying that plume-fed hot-spot magmatism is a key contributor to volcanism on Lanzarote Island.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

The 2022 Meradalir eruption of the 2021-23 Fagradalsfjall Fires, Reykjanes Peninsula, and associated phenomena

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The Meradalir eruption began on 3 August 2022 and lasted until 21 August 2022. It was the second of a series of three eruptions to date, bracketed by the 2021 Geldingadalir and 2023 Litli Hrútur eruptions. Together these eruptions make up the Fagradalsfjall Fires – the opening phase of the current eruptive period on Reykjanes Peninsula, Iceland. The eruption began with >8 vents on a ~250 m-long fissure, later focusing on a single vent that produced $5.7\times10^6 \pm 7.6\times10^5$ m^3 of lava (dense rock equivalent, 30% porosity) over 1 km^2. Key features included a spatter cone vent, a perched lava pond, and four rubbly pāhoehoe lobes. The vent edifice, primarily dense spatter bombs, reached dimensions of 89×105 m and 18 m high with slopes of 25°–30°. The perched lava pond, formed within hours in a bowl-like depression, reached a maximum height of 35 m by day 9 before draining. The lava field was emplaced over the top of 2021 lava and consisted of four rubbly pāhoehoe lobes each with lengths of approximately 1.4 km. The similarity of these three lengths suggests that 1.4 km was the critical length of lavas emplaced in this scenario. The weight of the 2022 lava compressed the underlying 2021 lava field and forced still-molten 2021 material out through tumuli cracks which flowed along the valley margins as ropey and slabby pāhoehoe. Lidar surveys revealed that the surface of the 2021 lava had bulged by 3 m in the south and 3.6 m in the north.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

Lava fountaining dynamics on 4 of May during the 2021 Geldingardalir eruption, Reykjanes Peninsula, Iceland.

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On 19 March 2021, an eruption began in the Fagradalsfjall volcanic system in Iceland, marking the first lava emission on the Reykjanes Peninsula in 781 years. The 2021 Geldingardalir eruption featured nearly 7000 short-lived fountaining episodes, exhibiting an unusual diversity of episodic behaviors. This study focuses on the third phase of the eruption, particularly the period from May 2 to June 10, 2021, when pulsating episodes occurred with exceptional frequency. Lava fountaining activity on 4 May was quantified, analyzed, and interpreted, with a focus on videos captured with a 4K camera between 16:00 and 17:00 GMT. Pulse height, pyroclast exit velocity, and fountain height were quantified, with fountaining heights ranging from 120 to 160 meters and episode durations between 164 to 312 seconds. The pyroclast exit velocities measurements ranged from 16.3 to 20.2 m/s.This study also identifies a link between ongoing fountaining activity and volcanic tremor, showing that tremor episodes began shortly before, and lasted slightly longer than, visible fountaining. The fountaining frequency on May 4 averaged 6-8 episodes per hour, with a mean episode duration of 5.5 minutes (±1.1 min) and repose intervals averaging 2.5 minutes (±0.5 min).

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

Rapid geochemical and petrologic monitoring of Kīlauea's recent eruptions

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The University of Hawaiʻi at Hilo and the USGS Hawaiian Volcano Observatory collaborate in geochemical monitoring during Island of Hawai'i eruptions using energy-dispersive X-ray fluorescence (EDXRF) to analyze whole-rock geochemistry. These data provide information for hazard determination and risk assessment in near real time; analyses are often conducted on the same day as sample collection. These efforts track compositional changes and provide estimates of lava temperatures. Here we present the results from the eight eruptions of Kīlauea since the summit caldera collapse in 2018. Analysis of the six summit eruptions suggests that, the bulk composition of the shallow magma reservoir has become slightly more primitive. Whole-rock MgO was higher in 2020 compared to the 2018 compositions, and MgO has increased almost 1 wt% over 2020-2025. EDXRF analyses also indicate that the lava erupted in June 2024 from the Southwest Rift Zone had accumulated olivine, while the September 2024 middle East Rift Zone eruption is chemically similar to past eruptive events in the area. Petrological studies of olivine and other mineral phases provide additional context for changes since 2018. Olivine macrocrysts from summit eruptions include three populations that are distinguishable by their compositions, zoning patterns, and textures which indicate storage for crystal cargo at 3–5 km depth (South Caldera reservoir), 1–2 km depth (Halema'uma'u reservoir), and from within the post-2018 lava lake. Collectively, these efforts provide important and timely information about the dynamic nature of Kīlauea's frequent eruptions and changes in the system since 2018.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

Diffuse He/CO2 and H2/CO2 from Cumbre Vieja volcano during the Tajogaite eruption, La Palma, Canary Islands

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La Palma (708 km^2), located northwest of the Canary Archipelago, is one of the youngest islands (~2.0 Ma) and the most volcanically active according to historical records. On September 19, 2021, a volcanic eruption occurred in the southwestern sector of the Cumbre Vieja rift zone, the most active basaltic volcano in the Canaries. The eruption is considered as a basaltic fissure type, dominated by strombolian activity and with episodic phreatomagmatic pulses, concluding on December 13, 2021. This study focuses on the diffuse emissions of He, H_2 and CO_2 from the soil atmosphere of Cumbre Vieja, emphasizing the He/CO_2 and H_2/CO_2 ratios, considering that He and H_2 are highly mobile gases. He is chemically inert, radiologically stable, non-biogenic, highly mobile and poorly soluble in water, while H_2 is abundant in volcanic and hydrothermal systems and a key participant in redox reactions within hydrothermal reservoirs. Since 2002, and at each survey, soil gas samples have been regularly collected at ~40 cm depth using a metal probe at 600 sites. He was analyzed using a QMS-type spectrometer, while H_2 and CO_2 were measured with a micro gas chromatograph. Spatial distribution maps constructed by sequential Gaussian simulation showed significant increases in He/CO_2 and H_2/CO_2 ratios before and during seismic swarms (2017-2021). During the eruption, these ratios also increased with the occurrence of volcanic tremor and preceded the peak of diffuse CO_2 emissions. In the absence of visible gas emissions (e.g. fumaroles, plumes), diffuse degassing surveys are essential geochemical tools for volcanic monitoring purposes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

Eruptive dynamics of a long-lasting, hybrid eruption: physical and textural characterization of the 2021 Tajogaite eruption (La Palma, Spain)

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Hybrid eruptions comprise of effusive and explosive behaviour occurring simultaneously or in quick succession. In long-term records, this activity tends to be overlooked due to the challenges of identifying simultaneous activity from deposits. Therefore, the study of tephra sequences associated with well-documented hybrid eruptions is particularly valuable. The recent Tajogaite eruption (Canary Islands) lasted for 86 days and the eruptive activity consisted of effusive activity from the base of the newly-formed cone and contemporaneous explosive activity from the summit vents. A textural, morphological and geochemical characterization of the juvenile material ejected during the Tajogaite eruption is presented to frame changes in eruptive dynamics and underlying conduit processes. We distinguish three eruptive phases: the high intensity Phase I contains highly vesicular clasts of irregular to spongy morphology and a wide range in vesicularity (~55-68%), while volume-normalised vesicle numbers N_V^m show limited variability ($11.4\text{-}16.6 \times 10^6$ cm^{-3}). Phase II marks an overall decrease in eruption intensity towards more intermittent activity. The associated juvenile material shows a lower, limited vesicularity, with variable N_V^m and irregular to subspherical morphologies. In the final Phase III, eruption intensity increases again, with pyroclasts displaying variable morphologies, high N_V^m values ($24\text{-}85.2 \times 10^6$ cm^{-3}), and ~60% vesicularity. The observed morphological and textural variability of the tephra indicate syn-eruptive changes in the conduit that can be related to the presence of multiple, simultaneously active conduits with different geometries. These exert a temporally and spatially variable control on magma outgassing, fragmentation and crystallization, resulting in the observed hybrid activity.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.6: High resolution syn-eruptive documentation and analyses of recent basaltic eruptions

Allocated presentation: Poster

Does benchtop micro-XRF fill volcano petrology's value gap? An appraisal using the Tajogaite eruption time-series, La Palma, Canary Islands

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Volcano petrology brings the most value to monitoring efforts when it is not only accurate, representative, and insightful, but also rapid, frequent and integrated. Yet, petrology is logistically challenging and traditionally expensive to implement at the scales required. Here we hypothesize that petrology's value can be maximised by combining state-of-the-art, benchtop, microscale X-ray fluorescence (µXRF) and automated mineralogy methods (e.g. AMICS or open-source). µXRF requires only a sawn surface to analyse and provides rapid textural and per-pixel compositional analysis at the microscale. A typical thin-section sized area can be analysed at 25 µm resolution in <4 hours with no coating required, and whole-rock composition determination by signal integration. We analysed >40 lava samples from the 2021 Tajogiate eruption of Cumbre Vieja, La Palma multiple times using different instrument settings. We evaluated the results with direct reference to published petrological time-series data, including that from the same sample surfaces analysed by QEMSCAN, EPMA, and LA-ICP-MS, as well as their splits analysed by destructive XRF and XRD. A value matrix was populated with the overall goal of comparing the scientific insights achieved against the time it took to recover them. We found that a well-calibrated µXRF coupled with tuned data-processing algorithms can produce accurate, representative, and insightful petrology from multiple samples in a 24 hour period. The datasets also support targeted and specialised analytical methods with higher resolution and sensitivity that leads to workflow efficiency gains, demonstrating that benchtop µXRF fills a value gap between high-resolution field sampling and high-resolution petrological analysis.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk [Invited]

Geometrically complex magmatic plumbing system revealed by high-silica rhyolite glasses from the Highland Range Volcanic Sequence (NV, USA)

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Monitoring and predicting eruptive behavior at silicic volcanoes requires an improved understanding of where rhyolites are stored prior eruption. In this study, we (1) estimate magma storage pressures from matrix and quartz-hosted melt inclusion glasses in four high-silica rhyolite units from the Highland Range Volcanic Sequence (HRVS; NV), and (2) utilize glass trace element compositions to evaluate the geometry of the HRVS plumbing system. Melt inclusion vapor saturation pressures suggest minimum pressures of ~100 MPa for magmas that produced rhyolitic tuffs and ~100-130 MPa for those that produced a block-and-ash and an obsidian flow. Matrix glasses from all samples give deeper average Rhyolite-MELTS quartz+2feldspar and quartz+2feldspar+oxides pressures (134 ± 39 MPa and 146 ± 28 MPa, respectively). Pressure estimates from a new machine-learning geobarometer, MagMaTaB, are highly sensitive to the choice of phase assemblage: results using a quartz+2feldspars+oxides assemblage are similar to quartz+2feldspar±oxides rhyolite-MELTS and melt inclusion vapor saturation pressures for all samples (109 ± 46 MPa), but a quartz+2feldspar-only MagMaTaB assemblage leads to significantly higher pressure estimates inconsistent with other results (238 ± 36 MPa). Regardless of the method used, pressure results suggest storage of the HRVS rhyolitic magmas at similar depths. However, variations in matrix glass Rb, Ba, Sr, and Eu through the HRVS stratigraphy cannot be explained by fractional crystallization, suggesting the eruptions were likely tapping separate magmas. The outcomes of this work indicate that the pre-eruptive storage of the HRVS magmas was geometrically complex, with several discrete eruptible melt lenses residing at 4-5 km depth.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

Revisiting Tajao: using banded pumices to untangle magma dynamics in an intra-cycle eruption from the Las Cañadas volcano, Tenerife (Canary Islands)

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Banded pumices are widespread among explosive eruptions and are frequently regarded as evidence of pre- and syn-eruptive magma interactions in the plumbing system. Therefore, their study provides detailed information on the magma dynamics preceding and/or triggering eruptions. We present a petrological and geochemical study of banded pumices from the 320 ka Tajao eruption, a small (~3 km^3 DRE), intra-cycle event belonging to the Diego Hernandez Formation (DHF), Las Cañadas edifice (Tenerife, Canary Islands). Although the Tajao banded pumices resemble those from other DHF ignimbrite bodies (e.g. El Abrigo [1]), major and trace element glass and mineral chemistry suggest different magma dynamics and end-member compositions. Compared to El Abrigo banded pumices, Tajao groundmass glass chemistry is more complex, with a trimodal distribution and more restricted composition range. Their trace element concentrations suggest a lesser contribution of evolved feldspar-rich magma mushes. In contrast, mafic glasses are tephritic-phonotephritic in composition and suggest the involvement of a Cpx-Krs-Pl bearing component, similar to El Abrigo mafic endmember. Complex mixing and mingling textures between mafic and silicic melts are ubiquitous. Furthermore, thermobarometric estimates on zoned Na-rich pyroxenes indicate significant heating of the phonolitic reservoir before the eruption. Our results expand previous work [2] and improve our knowledge on the long-term evolution of the DHF shallow phonolitic reservoir, which eventually led to the large-volume El Abrigo eruption at ca. 170 ka, the last caldera-forming eruption on Tenerife. [1] González-García *et al.* (2022). J. Petrol. 63(3), egac009 [2] Wolff, J. A. (1985). Geol. Mag. 122(6), 623–640

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

Micro-analytical perspectives on the trans-crustal magma plumbing system feeding the Millennium Eruption of the Tianchi volcano in the Changbaishan volcanic field, northeast China

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The Millennium Eruption (ME) of the Tianchi volcano is the most voluminous eruption in the Changbaishan volcanic field. However, the pre-eruptive storage conditions and magma dynamics of the Tianchi magma reservoirs feeding the ME remain elusive. In this study, we investigate the whole-rock, mineral, and glass chemistry of the various ME products, including comenditic white pumices, trachytic grey pumices, and the mafic enclaves. Olivine and clinopyroxene in the white pumices have lower Mg# values than those in the grey pumices, indicating that the comenditic phase is more evolved than the trachytic phase. However, alkali feldspar phenocrysts in both pumices have similar compositions, suggesting pre-eruptive mingling of the comenditic and trachytic magmas. The phenocrysts in the mafic enclaves are equilibrated with the whole-rock composition of Tianchi trachybasalts, indicating mafic enclaves are also trachybasaltic. Thermobarometric calculations show that the ME comenditic and trachytic magmas have temperatures ranging from ~700 to 800 °C and ~800 to 900 °C, respectively, and both are stored at pressures of ~1 kbar, suggesting a single thermally and compositionally stratified upper crustal silicic magma reservoir. The wide pressure range (~2 to 8 kbar) of trachybasaltic magma likely implies multiple trachybasaltic lenses located at mid- to lower-crustal depth. Together with Rhyolite-MELTS modelling results, we propose that a two-stage magma fractional crystallization process of trachybasaltic melts results in the ME silicic melts. The recharge and mingling of the trachybasaltic magma with the silicic magma result in tumescence and rejuvenation of the upper crustal magma reservoir, finally triggering the explosive ME.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

A dendritic growth mechanism for producing oscillatory zoning in igneous zircon

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The concentric oscillatory zoning pattern of igneous zircon is generally interpreted as evidence for core to rim growth during magmatic crystallization. This interpretation anchors a wide variety of qualitative and quantitative studies of zircon age, chemistry, and texture. Here, we show via detailed trace element mapping that euhedral magmatic zircon with apparently typical CL oscillatory zoning instead show evidence of dendritic growth. This observation challenges the unique interpretation of oscillatory zoning in zircon. Dendritic growth occurs under conditions of substantial undercooling, resulting in disequilibrium trace element concentrations in the zircon. Geochronological and geochemical analyses of zircon with this type of growth history require a different interpretative framework with significant implications for timescales of magmatic and volcanic systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

Contrasting styles of silicic magma mixing dynamics in Turkana Basin, Kenya: Insights from high-resolution tephrochronological tools

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Distal volcanic products are crucial for building a tephrochronological framework and can serve as important messengers of the volcanic processes that produced them. The Turkana Basin, NW Kenya, located within the East African Rift System has been subjected to multiple episodes of silicic volcanism, resulting in numerous volcanic ash layers (tuffs) intercalated with paleoanthropologically significant fossiliferous horizons. Whilst the tuffs and their entrained pumice clasts have been frequently targeted for tephrochronological reasons, there is limited knowledge on the petrological implications of these volcanic products. Here we provide a comprehensive study on the feldspars, pumice and tuff glass chemistry of two distinct tuff layers- the Middle Nariokotome (MNK) and the Morutot tuffs - by utilizing a combined methodology of high-precision $^{40}Ar/^{39}Ar$ geochronology, and shard-specific major and LA-ICP-MS trace element geochemistry. High-precision ages from individual feldspar grains reveals significant age dispersions (~206kyr for MNK and ~60kyr for Morutot) suggesting 'cold storage' of feldspar crystals. In addition, pumice and tuff glass geochemistry indicate contributions of less evolved silicic magmas leading to heterogeneous geochemical signatures on a clast-scale and possibly triggering eruptions. For the MNK tuff, we see two distinct geochemical components, suspected to result from mingling of magmas. In contrast, the Morutot volcanic products reveals evidence of chemical mixing of magmas through chaotic dynamics, leaving complex signatures typified by contemporaneous pumice clasts that exhibit either intra-clast heterogeneity or homogeneity. Altogether, this integrated approach refines the tephrochronology of the Turkana Basin and also provides critical insights into the regional silicic magma dynamic processes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

Crystal Cargoes in 4 Dimensions: Mafic Rejuvenation Prior to the 2021 Tajogaite Eruption of Cumbre Vieja, La Palma.

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Studying crystal cargoes in basaltic magmas is key to understanding magma evolution and eruption dynamics. Crystals grow, settle and accumulate, forming mushes often remobilized during magma recharge events. Thus, crystal populations may not all reflect equilibrium growth with the melt. The role of crystal mushes in magma diversity remains an active research area. Traditionally, crystal studies relied on random slices through samples, introducing sectioning effects complicating interpretation of pre-eruptive processes. Here we present crystallographically controlled 2D (BSE, EPMA) and 3D (µCT) textural and compositional data on 127 euhedral, compositionally zoned clinopyroxene and olivine macrocrysts (1-2 mm) to reconstruct magmatic processes prior to the 2021 eruption of Cumbre Vieja (La Palma, Canary Islands), and assess the genetic origin of the crystal cargo. We handpicked crystals from tephra from four different eruptive phases to investigate syn-eruptive magmatic changes and performed diffusion chronometry to infer magmatic timescales. All clinopyroxene and most olivine macrocrysts present reverse core-to-rim zoning, with low Mg# antecrystic cores (44-67% vol) overgrown by high Mg# autocrystic rims (28-41% vol). Interestingly, we find systematic textural and chemical differences across eruptive phases; for instance, late-stage crystals record reaction with particularly hot, primitive magma. We propose that mafic rejuvenation drove reactivation of Cumbre Vieja, and that rejuvenation to eruption timescales were on the order of two weeks to two months. In addition, this study illustrates a sample preparation and analytical protocol that helps to overcome traditional challenges in crystal studies deriving from random sectioning effects.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

Pre-eruptive volatile conditions as captured by the apatite record in the crystal mush system of Las Cañadas Caldera, Tenerife

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Magma is believed to be stored in the crust as crystal mushes. However, crystal-rich mushes will not be readily mobile and the ways that they are mobilised and erupted is not fully understood. This study assesses whether magmatic volatiles contribute to crystal mush mobilisation, through use of the apatite volatile record. Apatite records changing melt volatile contents by incorporating volatiles (H_2O, F, Cl) into its crystal structure, capturing the timing of volatile exsolution in a magma. Using apatite inclusions found in pumice-derived phenocrysts and primocrysts from cumulate nodules interpreted as in-situ mush, we interpret the changing volatile state of the crustal mush column prior to and at the onset of eruption. Pumices and nodules represent a mush ranging in magma composition from basanite to phonolite, with different magma compositions having distinct apatite volatile trends. We use a forward model to fit the compositional range of each apatite population. Our results show that, within a compositionally variable crystal mush, a shallow level, volatile-saturated phonolite reservoir existed. This reservoir was disturbed by an ascending phonotephritic magma initially stored at lower crustal depths in volatile-undersaturated conditions. Volatile saturation occurred in this phonotephrite due to primary boiling and supplied gas to the upper phonolite reservoir. This may have sufficiently destabilised the system to cause eruption. Our work shows that volatile-saturated and undersaturated magmas can exist within one system, and that late-stage volatile saturation of undersaturated parts of the system may be key to mobilisation and eruption of crystal mushes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

Explosive eruptions at Tandikat volcano, Sumatra (Indonesia): Insights into two temporally proximate eruptions in the last 5000 years

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The island of Sumatra is home to over 130 active/potentially active volcanoes with explosive eruptive histories. Of particular interest is Tandikat (TDK) volcano that was attributed as the source of two temporally proximate explosive eruptions – the magnitude ~5.6 Tandikat I (TDK I) at ~4.94 ka and the magnitude ~5.2 Tandikat II (TDK II) at ~4.36 ka. Despite the improved eruption record, little is known about the catalyst for two explosive eruptions occurring only ~580 years apart. Here, we reconstruct the magma plumbing system (composition, pressure (P), temperature (T) and volatile budget) through pyroxene, amphibole and melt thermobarometers, as well as an apatite-based melt hygrometer. Preliminary results indicate bulk rock and glass compositions of basaltic andesite and low-silica rhyolite, respectively. Magma storage P-T estimates from different minerals show consistently higher values for TDK II (T=950-1150°C and P=350-650 MPa from two-pyroxene; T=850-950°C and P=300-500 MPa from amphibole) in comparison to TDK I (T=900-1100°C and P=300-600 MPa from two-pyroxene; T=800-900°C and P=250-450 MPa from amphibole). Syn-eruptive P-T estimates from matrix glass occur within similar ranges for the two eruptions, i.e., 800-900°C (median=850°C) and 200-400 MPa (median=220 MPa). The range of melt water estimates (~3-5 wt.% from apatite) are also analogous for these eruptions. Calculations using the melt water content and existing solubility models indicate that for a magma containing ~5 wt.% H_2O to reach volatile saturation at ≥220 MPa, at least ~950 ppm CO_2 is required. Further constraints on the volatile budget will be obtained by ongoing work on melt inclusions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

Thermal Dynamics and Crystal Accumulation: Unraveling Magma Differentiation at Fogo Island, Cape Verde

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Magma differentiation at oceanic islands typically occurs in small reservoirs connected by vertical conduits that transport magma. Here, we explore whether these conduits can also serve as temporary magma reservoirs. Fogo Island is the most active volcano in the Cape Verde Archipelago, last erupted in 2014. The volcano summit exposes ca. 150 Ka of volcanic activity along the caldera walls with aphanitic to ankaramitic lava flows and magmatic breccias intersected by numerous dykes. Geochemical analyses of dykes and lava flows show a wide compositional range from foidites to tephriphonolites (2–15 wt% MgO), largely influenced by mineral accumulation of up to 70%. By combining whole-rock and mineral chemistry, this accumulation effect can be corrected, revealing a differentiation model dominated by clinopyroxene crystallization, with minor olivine and Fe-Ti oxides. Clinopyroxene consistently displays a Mg# of 74–78 across all samples, suggesting that the volcano's thermal structure governs crystallization conditions. A 1-D thermal model simulating repeated dyke injections—based on eruption frequency—shows that temperatures in the volcano's root zone remain above 950–1000 °C for extended periods. This sustained heat controls magma differentiation and explains the intermediate compositions observed. We propose that vertical conduits temporarily store magma, allowing minerals to crystallize and segregate during transport or between eruptions. Subsequent magma injections remobilize this stored magma, accounting for mineral accumulation in ankaramitic rocks and the diverse cumulates in Fogo's dykes and lava flows. This model offers valuable insights for forecasting the magma composition of upcoming volcanic activity on oceanic islands.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

The evolution of Mesozoic magmatism in the Levant margins: melt inclusions perspective on source composition and geodynamic processes

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Continental rifts are considered a hallmark of intraplate alkaline magmatism as they provide the tectonic, thermal, and compositional conditions necessary for magma generation. However, the structural evidence does not always support extensional tectonism when it comes to prolonged magmatism. The opening of the Neo-Tethys Ocean during the Late Paleozoic–Early Mesozoic exemplifies this, as the southern Levant margin evolved from syn- to post-rift settings. This geodynamic transition is recorded by sequential intraplate mafic magmatism in Makhtesh Ramon, Negev Desert, S Israel. Here, using multiple microanalytical techniques we analyzed olivine-hosted melt inclusions from two volcanic sequences: the late Triassic Saharonim sub-alkalic basalt, and the early Cretaceous alkali basalt-basanite-nephelinite at Ga'ash Hill. Triassic rifting produced voluminous magmatism with a narrow compositional range, dominated by a CO_2-metasomatized peridotite source. Pyroxenite formation during this period contributed to the diverse, low-degree melts of the early Cretaceous. Both formations host CO_2-rich melt inclusions (up to 3.15 wt.%, some of the highest levels documented in continental OIB-like magmas), indicating a carbon-rich source with up to 850–640 ppm C. Combined with ~0.5 wt.% H_2O, entrapment pressures ranged from 6–8 kbar (late Triassic) to 8–11 kbar (early Cretaceous), suggesting melt storage at lower crust–lithospheric mantle depths. The continental Moho likely functioned as a buoyancy barrier for ascending melts. While melting in the Triassic was initiated by mantle decompression, small changes in the tectonic or internal heat regimes could have caused melting of the readily fusible carbonate and pyroxenite bearing early Cretaceous mantle.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Talk

Time scales on melt extraction derived from garnet xenocrysts in felsic plutonic rocks

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Volcanism in Earth's continental crust is dominantly fed by transcrustal magmatic plumbing systems but one of the fundamental issues of such systems is the timescales by which magmas ascend through the crust. Here we present major and trace element data and maps to document timescales of a multiple growth history for garnet xenocrysts entrained in an upper crustal magma body from the Sesia magmatic system (Ivrea zone, northern Italy). Based on phase diagram calculations and garnet compositional variations, metamorphic cores of garnet in the plutonic rocks either originate from granulite facies lower crustal rocks (ca. 8-9 kbar), or metasedimentary enclaves at mid crustal levels (ca. 6.8 +/- 1.2 kbar). The contrasting metamorphic conditions indicate that the Borgosesia monzogranite has accumulated xenocrysts from different depth along its ascent path from the lower crust to the emplacement level at ~3 kbar. Rhyolite-MELTS modeling was used to explore decompression and cooling paths of hydrous rhyodacitic magmas and its effects on the density and viscosity evolution of the system. Simple calculations using hindered settling indicate garnet grain settling velocities of ca. 0.5 – 0.8 $m.yr^{-1}$ which correspond to maximum time scales of magma ascent of ~20-30 kyr. This is the same order of magnitude as derived from multicomponent diffusion calculations in garnet (~5 - 12 kyr). Garnet xenocrysts provide strong constraints on ascent rates of moderately hydrous siliceous magmas derived from the lower crust.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Amalgamation of multiple, discrete magma bodies fueled the tuff of Elevenmile Canyon

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The occurrence of super-sized eruptions (>1000 km^3) implies that staggering quantities of eruptible magma must have existed in the crust over relatively short time periods. However, the architecture of these systems remains elusive, particularly for crystal-rich systems. One such eruption in western Nevada, the tuff of Elevenmile Canyon (25.1 Ma), is compositionally variable (~65-78 wt.% SiO_2), crystal-rich (20-60%), and enormous (<5000 km^3 total erupted volume). Here, we expand on the bulk rock geochemistry determined by previous workers with major and trace element analyses of glasses from individual fiamme and vitrophyres. Our samples span the bulk compositional and stratigraphic extent of Elevenmile. We identify multiple distinct glass populations in major and trace elements, and the span of major element compositions mimics the bulk tuff compositional range (e.g., 66-78 wt.% SiO_2). Zircon saturation thermometry also reveals discrete temperature populations of ~800-850 °C associated with more evolved (75.5-78 wt.% SiO_2) glasses and ~900-925 °C associated with less evolved (67-75 wt.% SiO_2) glasses. Fractional crystallization alone cannot explain trace element differences between samples. Different fiamme populations display variable mixing and mingling textures in single hand samples, which supports magma mixing as an important process in the generation of the observed compositional variability. However, other samples contain compositionally homogenous fiamme populations, suggesting that open-system processes may have been localized. We conclude that the tuff of Elevenmile Canyon is more consistent with models describing giant eruptions as being sourced by the amalgamation of multiple, discrete bodies rather than the product of one zoned magma body.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Trace element fingerprinting of felsic cumulate recycling in igneous amphibole: A case study from Milos, South Aegean Volcanic Arc, Greece

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Numerous compositional and textural studies on igneous amphiboles document its utility as a recorder of magmatic processes, intensive parameters of magma storage and melt compositions. We herein explore the potential of fingerprinting evolved feldspar±zircon recycling from low-T felsic cumulates, by investigating the trace element systematics of amphiboles from the andesitic units of the Papafrangas (PFS) and Kalogeros (KAD) lava domes in NE Milos, Greece. The amphiboles are Mg-hastingsite/tschermakite and lack abrupt compositional zoning or extensive breakdown textures. The REE patterns of the amphiboles from PFS and KAD exhibit slight concave downwards patterns in LREE [$(La/Sm)_N$=0.6-1.7], flat HREE $(Tb/Yb)_N$=0.3-0.5], and slight negative Eu anomalies (Eu/Eu*=0.7-0.9). Additionally, they display lower V and Sc contents compared to Milos amphiboles with clear recharge affinity (mafic enclaves) and lack the pronounced negative Eu anomaly that characterizes hornblendes that crystallize from evolved melts. Furthermore, PFS and KAD amphiboles stand out within the entire Milos compositional dataset due to their higher Ba, Eu, Zr and Hf contents. Such element records in various phases (e.g. plagioclase, glass) have been widely used to trace cumulate recycling in igneous systems (Elis et al. 2023). Partitioning of these moderately to highly incompatible elements in amphibole, along with the high Zr and Ba contents in the equilibrium melts, is inconsistent with evolution along a liquid line of descent and suggests an input from a cumulate melt component. We propose that amphibole should be regarded as a potential recorder of low-T cumulate recycling, offering additional insights into the petrological evolution of igneous suites.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

The petrology and chemostratigraphy of the Vitafumo and Miliscola tuff-cones: a key to the pre- and syn-eruptive processes during the ancient, pre-caldera stage of the Campi Flegrei volcanic field (southern Italy)

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The monogenetic volcanoes of Vitafumo and Miliscola emplaced some of the oldest deposits of Phlegrean volcanism, cropping out along the SW border of Campi Flegrei caldera. The two edifices formed one shortly after the other as the products of explosive eruptions emplacing alternating fallout and pyroclastic density current deposits. The juvenile fractions from the two successions were sampled throughout the entire stratigraphic sequences (up to 130 and 50 m thick, respectively for Vitafumo and Miliscola), which allowed for a complete chemostratigraphic investigation. This offered a unique opportunity to reconstruct the architecture of the plumbing systems of ancient Phlegrean volcanoes, whose study is generally obscured by two caldera collapses, abundant cover by younger deposits and intense urbanisation. Vitafumo and Miliscola juvenile clasts appear remarkably crystal-poor, the older Vitafumo volcano being slightly crystal-richer and featuring microphenocrysts/microglomerocrysts of sanidine and plagioclase mainly, while Miliscola pumice clasts are aphyric and display a glassy groundmass with variable amounts of sanidine microlites. Compositions are trachytic and in line with the generally strongly evolved Campi Flegrei pre-caldera products, with Miliscola samples being slightly less evolved as indicated by lower SiO_2, Rb, Zr and Nb and higher TiO_2, Fe_2O_3tot, CaO, Sr, Ba and V. No chemostratigraphic trends are apparent throughout the two pyroclastic sequences. These preliminary results suggest that in both feeding systems magma accumulation had allowed for extensive differentiation (likely accompanied by volatile enrichment) and homogenisation, supporting the idea that reservoir growth processes prevailed during the period preceding the caldera-forming eruptions at Campi Flegrei.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

What controls the compositions and eruptability of magmas in subduction zones? The Case of the Aegina Magmatic Province (Greece) from inception to extinction

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The Aegina Magmatic Province, situated within the South Aegean Volcanic Arc, offers insights into the evolution of a magmatic system in a subduction zone. This study investigates its complete volcanic life cycle from inception to extinction, leveraging zircon U-Pb geochronology and extensive geochemical data to unravel the factors controlling magma compositions, reservoir evolution, and eruptability during the magmatic activity in the area. The system was active for ~2.8 My with volcanic eruptions beginning at approximately 4.3 Ma following a prolonged (>500 kyrs) phase of magma reservoir nucleation and growth in the crust (without eruption), discernable only by zircon crystallization. The volcanic history includes two eruptive phases with varying eruption frequencies. Mineral chemistry reveals stable upper-crustal storage conditions throughout Aegina's lifespan, with significant temperature and water content variations linked to magma recharge events. Initially, the recharge consisted of hydrous, volatile-rich magmas, which fostered crustal magma storage, differentiation to andesitic/dacite composition, and intermittent eruptions of such intermediate compositions. Over time, the influx of drier magmas increased, leading to more frequent eruptions progressively diluting the volatiles in the upper-crustal reservoir. The increase of dry magma persisted into the final phase, causing the system to lose its capacity for long-term magma storage and differentiation, leading to the end of volcanic activity at ~2.1 Ma with dry basaltic andesites. The introduction of dry magmas correlates with significant changes in εHf in zircon crystals, suggesting variable amounts of crustal contamination with time, likely happening dominantly in the mantle wedge by sediment addition.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Cenozoic post-collision paleo lithospheric thinning of SE Kalimantan (Borneo), Indonesia: constraints from alkaline lamprophyre thermobarometry and geochemistry

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Abstract Modern igneous petrology is founded on the combined observations of active magmatic systems, petrochemistry, experimental petrology and geothermobarometry. These disciplines allow reconstruction of past igneous systems and petrotectonic processes. Therefore, with relevant samples and appropriate analytical techniques, aspects of paleo-lithospheric structure at the time of magma eruption or intrusion can be inferred. The present-day lithosphere in Borneo, Southeast Asia, is very thin due to extensional tectonics associated with the opening of the Makassar Strait (Burton-Johnson & Cullen, 2023; Murphy et al., 2024). However, the actual mechanism(s) behind this inferred stretching remains poorly understood. Here, we investigate the petrogenesis and geothermobarometry of shallow alkaline, petrologically diverse mafic sills and dykes that intruded into Eocene sediments in southeast Kalimantan (Borneo), Indonesia with the aim of gaining insights into the magma plumbing system and Cenozoic paleo lithospheric architecture of the region. Rock samples, including alkaline (camptonite) lamprophyres and alkali olivine basalts from peninsular Senakin and Petangis in southeast Kalimantan were collected for this study. Whole rock geochemistry and in-situ analytical techniques will be used to constrain the P-T conditions the magma plumbing systems that fed the dykes and sills. Findings from the study will offer insights into the Eocene crustal thickness in southeast Kalimantan with implications for the thickness of the Cenozoic lithosphere prior to regional extension. Results will also enhance our understanding of the mechanism(s) driving the extensional tectono-volcanic evolution of the region.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Subduction or Intraplate? Granitoids in the Virgin Islands and implications for the growth of early-Earth-like continental crust

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A compositionally heterogenous suite of tonalite-trondhjemite-granodiorite (TTG) rocks comprise the oldest preserved continental crust. This material is considered to be generated through partial melting of metamorphosed mafic source rocks. However, the geological mechanisms in the formation of TTG remains poorly understood. Both subduction and intraplate settings are proposed environments of formation. Petrological studies indicate early-earth basaltic surfaces share similar compositions to both Mesozoic Ocean plateaus and island arc basalts (IAB). This suggests that Archaean TTGs may have been formed from partial melting plateau and/or IAB compositions via subduction or intraplate processes. The Virgin Islands (VI) are a collection of over 100 islands located in the northeastern corner of the Caribbean plate. Since ~60 Ma, the 15-20 km thick Caribbean oceanic plateau has been underthrusting and subducting beneath the North American plate. This has formed two distinct tectonic environments in the VI: (1) an intraplate environment in the southern islands, with ~30 km of stacked ocean plateau and IAB material; and (2) deeper subduction towards the north. Through geological mapping and sampling, granitoids with TTG compositions have been identified throughout the VI, therefore providing a unique opportunity to determine whether these early-Earth-like TTGs have been derived from metamorphosed IAB and oceanic plateau material from the southerly intraplate setting and/or the northerly subduction environment. Here, we present field observations, initial whole rock major and trace element analyses and preliminary mass balance partial melting and fractional crystallization modelling for chosen starting compositions to determine the pressure-temperature conditions required to generate VI TTGs.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Vertical growth of caldera-forming crust: a case study of 50 ka Maninjau ignimbrite, Sumatran Fault Zone (SFZ), Indonesia

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Caldera-forming eruptions have significant social impact. It also has considerable impact on crustal evolution. We conducted geologic and petrologic study for 50 ka Maninjau caldera-forming eruption deposits (VEI=7), the Great Sumatran fault zone, Indonesia, to reveal large silicic magma processes extending throughout the crust. Maninjau ignimbrite consists of three eruptive units showing distinct ^{14}C ages and paleomagnetic directions, suggesting each eruption occurred spasmodically with a time gap of a few hundred years. Crystal-poor rhyolite, represented by white pumice, was likely derived from ephemeral eruptible magma episodically (three times) extracted from deeper crystal mush zone. A minor amount of crystal-rich andesite (gray pumice) can be interpreted as dispersed fragments from the mush. Estimated depths from “extraction” and “storage” pressures by using rhyolite-MELTS for crystal-poor rhyolite are 1.6–7.5 km and 1.7–21.7 km, respectively. Both storage/extraction depths become shallower and wider in later units. The shallower magma system at later stage might have been situated on top of former, melt-depleted mush zone compacted by subsidence of roof block(s) with segregation/evacuation of large amount of silicic magma. The depleted and compacted mush zone after former eruption might remain high heat transfer for maintaining next partial melting at shallower level, resulting in thickening of mush zone. Temporal shallowing of storage/extraction depths is also observed at Taupo Volcanic Zone, New Zealand, which may have related to tectonic controls by crustal extension. We need additional work (e.g. thermal modeling, tectonic stress field simulation) to fully explain the vertical growth of caldera-forming crust.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

New insights on the petrology of the ancient activity of the Roccamonfina volcano (central-southern Italy)

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Roccamonfina is an extinct stratovolcano of the Italian peninsula where leucite-bearing ultrapotassic products are generally considered to predate leucite-free shoshonitic products. This relationship is largely based on studies conducted on lavas, while pyroclastic successions have been generally overlooked due to their poor preservation. Here we report a detailed petrological investigation of the juvenile products from pyroclastic deposits of the oldest stages of the volcano activity (i.e. >350 ka) cropping out on the eastern side of the edifice. Most of the samples are represented by crystal-poor pumice clasts with few clinopyroxene and sanidine microphenocrysts set into a brownish, glassy groundmass with sparse, variably altered to fresh leucite crystals. A smaller number of samples are relatively crystal-rich and feature clinopyroxene, altered leucite and biotite phenocrysts plus variable amounts of sanidine and plagioclase, depending on the rock composition. Glass compositions range from phonotephritic to phonolitic, in line with the compositions of the oldest Roccamonfina lavas. In addition, leucite-free juvenile clasts were also observed. These clasts are typically crystal-poor, and featuring only rare alkali feldspar and clinopyroxene phenocrysts set into a trachytic groundmass whose compositions are in line with that of the most recent shoshonitic products. Interestingly, leucite-bearing and leucite-free samples display comparable Sr (0.70900-0.70939 vs. 0.70872-0.70913) and Nd (0.51217-0.51220 vs. 0.51220-0.51224) isotope ratios. These preliminary results indicate that the ancient Roccamonfina activity was significantly more complex than previously thought, featuring at least two different magma series possibly generated by different partial melting degrees of the same mantle source.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

First evidence for leucite-bearing products in the recent stages of activity of the Roccamonfina volcano (central-southern Italy)

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The Roccamonfina volcano is one of the first Italian potassic volcanoes to be investigated by detailed petrological studies, which revealed an overall time-related progression of magma compositions from leucite-bearing ultrapotassic to leucite-free shoshonitic. However, sparse accounts reported some deviations to this general scheme, suggesting that the petrological evolution of the volcano is more complex than previously thought. Here we report a detailed investigation of the products of the recent phase of the volcano history (i.e. <305 ka), including both lava and pyroclastic deposits from the eastern side of the Roccamonfina. Along with prevailing leucite-free products, leucite-bearing juvenile clasts and lava samples were also recognised, featuring phenocrysts of clinopyroxene and leucite (olivine) or of leucite only set into a groundmass with clinopyroxene, plagioclase and leucite or clinopyroxene and plagioclase. Bulk-rock compositions are in line with the that of the leucite-bearing products of the oldest stages (>350 ka), although higher SiO_2, Cr and Ni, and lower Ba, Sr and V contents are observed at similar degrees of evolution. Also, the compositions of glass from the pyroclastic deposits are in line with that of the oldest stages, being phonotephritic. Interestingly, the Sr-Nd isotopic compositions of the two groups of leucite-bearing rocks are strikingly different, with the youngest products showing lower $^{87}Sr/^{86}Sr$ (0.70653 vs. 0.70872-0.71079) and higher $^{143}Nd/^{144}Nd$ (0.51250 vs. 0.51211-0.51222). These preliminary results support the idea that leucite-bearing magmas were not confined to the oldest stages of Roccamonfina history and suggest that they were generated at different times from different mantle sources.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

New insights into the magmatic evolution of the Imbabura Volcanic Complex, Imbabura province, Ecuador

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The Imbabura Volcanic Complex is located within the Imbabura Geopark in Ecuador and is considered a potentially active system. The knowledge of its volcanological evolution has improved over time in the literature, yet this was essentially based on radiometric and lithostratigraphic studies, without considering an appropriate geochemical characterization of the magmatic processes and sources. In this work, we review published whole-rock major and trace element contents, Sr-Nd-Pb isotope compositions, petrographic observations and radiometric ages spanning the entire volcanic history of Imbabura (Old volcano and Young edifices). A petrochemical fingerprinting is used to evaluate the magmatic processes related to fractional crystallization (FC) and assimilation-fractional crystallization (AFC) with the timing of volcanism in the Imbabura complex. Our investigation shows that (i) Old Imbabura rocks (~60-40 ka) display a nearly pure FC trend in a log(Rb = incompatible element) vs log(Ni = compatible element) plot and a negative isotopic correlation between Sr and Nd ratios, suggesting that magma differentiation was dominated by olivine±pyroxene fractionation. (ii) After 40 ka: Young Imbabura lavas become more radiogenic in Pb with increasing concentrations of Al_2O_3 and Fe_2O_3, Na_2O depletion, as well as increasing Th/La ratios. The absence of correlation between Sr and Nd isotopic compositions with silica or any differentiation index, suggests a possible interaction of magmas with the lower crust (with concomitant fractional crystallization of amphibole±pyroxene in the AFC process). This research suggests that the Imbabura Volcanic Complex displays a magmatic plumbing system that has been evolving through time in the Late Pleistocene.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

The impact of magmatic volatiles on stability of subvolcanic reservoirs and eruptive style

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The presence of magmatic volatiles, particularly H2O and CO2, plays a critical role in the evolution of magma reservoirs, influencing depth of magma storage, size and recurrence intervals of volcanic eruptions, and eruptive style. As volatile elements exsolve from magmas, they can lead to crystallization, impacting the mobility of such magmas. They also form a compressible phase that significantly alters the mechanical behavior of reservoirs open to magma recharge. The changes in compressibility due to an exsolved volatile phase affects pressure conditions within the magma storage region, playing an important role in controlling the frequency of eruptions. Moreover, the existence of an exsolved volatile phase in the subvolcanic magma reservoir prior to eruption tend to maximize eruptive volumes, as the presence of gas bubbles fosters mobile magma to escape from its storage area. Finally, the exsolved magmatic volatile phase formed within the magma reservoir play a crucial role in the development of gas permeability during magma ascent in the volcanic conduit. This process is key to understanding the transition between effusive and explosive eruption styles, as permeability development due to bubble growth and coalescence in conduits allows for gas escape, which strongly reduces the explosive potential of eruptions. Therefore, the study of the amount and state of magmatic volatiles in magma reservoirs is key for understanding volcanic behavior and mitigating associated hazards.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Deconvolving the relationship between subtle shifts in geochemistry and dramatic changes in explosivity at Augustine Volcano, Alaska

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Augustine Volcano is the most historically active volcano in Alaska's Cook Inlet region, with seven confirmed eruptions since 1883. Underlying these modern ash deposits are thicker, coarser tephras that indicate significantly greater explosivity as recently as 390 ybp. To fill gaps in the eruptive history at Augustine, and by extension, address the factors that control eruptive style at intermediate arc volcanoes, we present a chemostratigraphic study of Tephras B, M, and C, the most explosive eruptions at Augustine in the past 1200 ybp. These eruptions produced lapilli of high-silica andesite, low-silica andesite, and banded pumice comprised of mingled compositions and/or textures. The higher-explosivity eruptions of Tephras B, M, and C contain a higher proportion of high-silica andesite (35-93%) compared to the explosive phase of the 2006 eruption (26-52%; Wallace et al., 2010). We find subtle differences in geochemistry between these eruptions, particularly within the low-silica andesite component, suggesting different mafic parent magmas in the explosive eruptions that produced Tephras B, M, and C. Some, but not all, increases in explosivity within a single eruption (evidenced by shifts to greater median grain size) are associated with a decrease in the relative proportion of high-silica andesite, an increase in the abundance of banded pumice, and subtle shifts in the composition of the high-silica andesite. We generate a chemostratigraphic record for these large explosive late Holocene eruptions to explore concurrent changes in eruption style and geochemistry and compare these results to the well-constrained, lower explosivity eruptions of the past 200 years.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Pre-eruptive conditions of the 800 BP Plinian Eruption of Quilotoa volcano (Ecuador)

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Highly explosive dacitic eruptions often follow prolonged periods of volcanic quiescence and multiple succession of recharges and reheating steps. Understanding these pre-eruptive "priming" steps is critical for understanding processes in the volcanic plumbing system. The 800 BP Plinian eruption (VEI=6) of Quilotoa volcano, in Ecuador, caused significant devastation due to pyroclastic density currents and severe regional impacts due to ash fallouts. Despite this, the petrological characteristics of its products remain insufficiently studied. This research uses petrology to reconstruct pre-eruptive conditions, to investigate potential triggers for the eruption, and to understand magma evolution prior to eruption. Three juvenile clast types —white pumice, gray pumice, and dense clasts— are identified within deposits from the tephra fallout and pyroclastic flow deposits. Whole-rocks are homogeneous medium-K calc-alkaline dacites (65–66 wt.% SiO_2), with rhyolitic groundmass glass compositions (70-79 wt.% SiO_2). The mineral assemblage includes plagioclase (An_{30-54}), amphibole (Mg# 59–78), biotite, Fe-Ti oxides (magnetite and ilmenite), and quartz, with minor orthopyroxene and apatite. Disequilibrium textures in plagioclase, such as sieve and patchy textures, and reverse zoning patterns, indicate shifts in pressure, temperature, and magma composition. Pre-eruptive conditions are preliminary estimated at 754 ± 40 °C, 433 ± 86 MPa (15 ± 3 km), with water contents (melt inclusions) of at least 6-8 wt.% (probably close to saturation conditions). We show that multiple successive magmatic recharges may constitute the main trigger mechanism for the eruptive activity, evidenced by disequilibrium textures and compositional variations (e.g. higher An, MgO, FeO in plagioclase rims).

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Unravelling the plumbing system of the oldest ignimbrite in Martinique using chemical segmentation of plagioclase and thermobarometry

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In Martinique, the Roches-Genty episode (~3 Ma) crops out as a thick (> 50m) stratigraphic sequence of pyroclastic falls and flow deposits, rich in large (>2 cm) pumices and displaying characteristics typical of an ignimbrite. Despite the singularity of these deposits, their chemistry, petrography, pre-eruptive conditions, and eruptive dynamics remain unstudied. The possibility of ignimbrites in Martinique has implications for volcanic hazards in the Eastern Caribbean. We combine physical volcanology, petrography, and geochemistry to provide insights into the evolution of the plumbing system of the oldest ignimbrite in Martinique. Chemical maps of major and minor elements were generated by electron microprobe analysis to classify the chemical and textural complexity of pumice from different sub-units of the Roches-Genty episode. We identify eight chemical zoning groups in plagioclase populations (An_{55-95}), and measure the Fracture Index and Vesicle Number Densities, parameters that can be used to calculate decompression rates. Thermobarometry suggests that pyroxene and amphibole crystallized in the upper crust (<3 kbar). Throughout the eruption, bulk pumice composition changes from dacite to andesite, and the plagioclase composition varies from An_{55-85} to An_{95}. Also, the variety of plagioclase zoning group combinations decreases from 28 (complex) to 2 (simple). We suggest that the early Plinian phases mixed various parts of a complex plumbing system, draining a differentiated dacitic magma stored in the upper crust. This was rapidly followed by a series of column collapse or crater overflow events responsible for the deposition of pumice-rich pyroclastic density currents and surges, involving more primitive andesitic magma.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Compositional Insights from the Precursory Cleetwood Eruption on the Lead-Up to Mount Mazama's Caldera Collapse

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The magmatic architecture and processes that produce and mobilize the large volumes of magma required for a caldera collapse eruption can be extremely complex. Precursory activity provides valuable insight into the state of a magmatic plumbing system immediately prior to climactic eruptions. Mount Mazama, in southwest Oregon, USA, produced a VEI 7 caldera collapse during its climactic eruption, resulting in one of the largest eruptions of the Holocene epoch. At least four precursor eruptions have been identified in the 200 years leading up to the climactic eruption. Of the four, the Cleetwood eruption occurred immediately prior to the climactic activity and is compositionally identical. However, although having seemingly tapped the climatic magma reservoir, the Cleetwood eruption terminated in an effusive flow before the system destabilized and triggered the climatic eruption only weeks later. Here we present new major and trace element data across multiple Cleetwood units to better understand: 1) the state of the precursory magmatic system immediately prior to the climactic eruption; and 2) the controls that determine whether an eruption from a system primed for a caldera collapse results in effusion and temporary quiescence, as with the Cleetwood, or large-scale collapse. Preliminary results from plagioclase and orthopyroxene compositions indicate that different Cleetwood units were derived from a variety of liquid compositions, suggesting a range of magma sources may have been involved.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

A broadly homogeneous magma reservoir evacuated during catastrophic submarine caldera collapse of Hunga Volcano, 15 January 2022 Tonga

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We present integrated geochemical results of whole-rock and microlite-poor glass for the 15 January 2022 Hunga eruption based on tephra deposits and submarine-sampled bombs and spatter spanning the entire eruptive sequence. Whole-rock samples from the 2022 eruption are andesite (56.5–59.1 wt% SiO_2), while glass extends to more evolved compositions (56.6–65.6 wt% SiO_2). The pre-climax (stage 1) glass is the most evolved with the highest SiO_2, K_2O, K_2O/TiO_2 and the lowest MgO and CaO/Al_2O_3. The main fall phases (stage 2–9) and the wanning phase (stage 10) have slightly less evolved glass compositions, with relatively small compositional fluctuations. Glass compositions are mainly divided into three groups, including low-Ti, low-K (group 1; dominant), high-Ti, high-K (group 2), and low-Ti, low-K (group 3). Group 1 is further subdivided into high-Mg (1a) and low-Mg (1b) subgroups. Group 1a represents the least evolved compositional group, which is the dominant glass population in all stages except the pre-climax stage. Group 1b is slightly more evolved compared to 1a and is only present in the first two stages. Both groups 2 and 3 are more evolved, with group 3 being depleted in FeO. Common swirly glass textures reveal melt mixing/mingling between groups 1 and 3. Our results suggest that the Hunga eruption tapped multiple melt lenses of broadly homogenous magma with minor heterogeneities controlled by variable crystallization of clinopyroxene and plagioclase. Additional inputs from a shallower smaller reservoir (group 1b), evacuated mostly during the early stages of eruption.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Advances in thermodynamic modelling tools for magmatic systems

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Retrieving the thermodynamic properties of magma-rock systems such as composition, phase/melt fraction, densities and thermal properties is essential for studying, quantifying, and modelling the reactive thermo-mechanical evolution of magma reservoirs. These properties are derived from experimental data and are used to calibrate thermodynamic models, which can then predict melt-rock phase equilibria using a so-called Gibbs free energy minimization. Here, we present recent advancements in modelling thermodynamic equilibrium in magmatic systems achieved with the open-source parallel software package MAGEMin. These include the addition of a new thermodynamic database for dry alkaline magmatic systems and the continued development of our new Julia-based graphical user interface (MAGEMinApp), which greatly simplifies the calculation of phase equilibria. MAGEMinApp's functionality include the calculation of Pressure-Temperature-Composition diagrams (P-T, P-X, T-X, PT-X), modelling of Pressure-Temperature-Composition paths (fractional melting/crystallization with assimilation/extraction), trace-element and zirconium saturation predictive modelling, specific heat capacity calculation accounting for latent heat of reaction, mineral and magma classification (e.g., TAS diagram), as well as a new sensitivity analysis tool to investigate the control of bulk-rock composition on phase assemblage stability.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Experimental constraints on the magmatic parameters controlling the 2022 eruption of Hunga Tonga-Hunga Ha'apai Volcano, Tonga

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The Hunga Tonga-Hunga Ha'apai volcano, located in the Kingdom of Tonga in the Pacific Ocean northeast of New Zealand, is part of the Tonga-Kermadec subduction zone and is renowned for its 2022 eruption, the most explosive volcanic event globally in the past century. This cataclysmic eruption generated acoustic waves that circled the Earth's atmosphere multiple times, propelled a volcanic plume into the mesosphere, and triggered a tsunami that swept across the Pacific Ocean, eventually reaching the coast of South America. In this study, we experimentally investigate the key physicochemical parameters driving the volcanic eruptions at Hunga by comparing the compositions of natural melts and minerals with those produced at the laboratory scale. Isothermal-isobaric crystallization experiments were conducted in a non-end-loaded piston cylinder apparatus and in an internally heated argon pressure vessel. The starting material is a basaltic andesitic lava from the older edifice eruptions, representative of the most primitive products at Hunga. The experimental conditions ranged from 200–300 MPa, 1000–1130 °C, and redox states between 0.5 and 3.5 log units above the quartz-fayalite-magnetite buffer, with H_2O_{melt} varying between 0.6 and 6.4 wt.% to simulate both fluid-absent and fluid-present crystallization scenarios. The mineral assemblage consists of titanomagnetite, clinopyroxene, plagioclase and orthopyroxene, with major oxides and components (diopside-hedenbergite-enstatite and anorthite-albite) closely matching those of natural crystals. The compositions of residual glasses reflect the basaltic andesite to dacite evolutionary trends within the Hunga's plumbing system, offering crucial insights into the pre-eruptive conditions of the magmas that fed the cataclysmic 2022 eruption.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

The magmatic-hydrothermal system of Laguna del Maule

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The 17ka ignimbrite eruption of Laguna del Maule (LDM), Chile was the first and largest postglacial eruption of the LDM complex, resetting the magma system, erupting mafic juveniles, and bringing granitic lithics to the surface from depth. Previous geophysical studies into the LDM magmatic system reveal magnetotelluric anomalies of >1 S m−1 at depths of 3-5km, consistent with a saline fluid stored in porous rock. We propose that the erupted granites were brought to the surface rapidly from depths consistent with this MT anomaly, and have facilitated fluid storage and flow at depth. The granitic lithics vary in composition, texture and physical properties; from fine-grained granodiorites to coarse-grained monzogranites. Among these lithics are coarse-grained, hydrothermally altered, highly connected, porous monzogranites. Connected porosity estimated with helium pycnometry reveals pore volumes up to 6% in the monzogranites. 2 dimensional analysis with SEM reveals pore networks form a fine (5-25 micron) plexus of long grain boundaries dominantly associated with the quartz phase. Miarolitic cavities are also present, containing predominantly quartz crystals. We suggest the alpha-beta quartz transition as a mechanism for generating in-situ, highly connected, intergranular pore networks among the quartz phase of the monzogranites. Cl in quartz reveals complex zonation textures, and Ti in quartz reveals both magmatic and hydrothermal crystallization has taken place. Quartz thermometry offers crystallization temperatures of 400-800 (+/- 5). Amphibole geothermobarometry estimates crystallization depths of 3-5km at temperatures of 600-800(+/- 30) and pressures of 0.5-2.5 kbar (+/- 0.2 kbar), consistent with the depths of the mmagnetotelluric anomalies.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Multi-elemental assessment of plagioclase-melt equilibria unravel episodes of crystal growth and provides clues on magma evolution

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Violent eruptive events in basaltic systems often follow input of hot, undegassed magmas in shallow magmatic reservoirs. Investigating how crystal and glass chemistry record such physicochemical changes in the system is critical to reconstruct the mechanisms driving sudden large scale explosive events in such settings, and may be integrated with crystal stratigraphy to recover the relative and absolute timing of eruption triggers. As such, it is of utmost importance to reconstruct such changes in natural systems through the record provided by crystals and glasses in the eruption products. The reconstruction of crystal-melt equilibria is crucial for a thermodynamically rigorous assessment of intensive properties of the magmatic system based on mineral compositions. In this respect, experimental constraints on crystal-melt partitioning are quintessential to the modeling of melt compositions and intensive parameters, performed by minimizing the strain energy determined by the substitution of isovalent trace cations in crystal lattice sites. In this contribution we combine numerical modeling with a multi-elemental approach to the study of intracrystalline compositional variations in a statistically representative data set of plagioclase compositions from Stromboli volcano. This approach, applied to a well-studied volcanic system, allows to constrain the chemical evolution of the system, assessing the role of disequilibrium effects and transient melt compositions existing ephemerally during crystal growth and dissolution episodes. Implications of this work extend from the reconstruction of magma dynamics at Stromboli to the definition of best practices to deal with the interdependence inherent in the treatment of intensive thermodynamic properties of magmatic systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Ejected fragments of magma mush in the Fish Canyon Tuff (Colorado, USA) and the processes within magma mush that feed crystal-rich supereruptions

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The Fish Canyon Tuff (Colorado, USA) erupted following the collapse of the La Garita caldera around 28 Ma and resulted in one of the largest-known ignimbrite deposits. This ~5000 km^3 ignimbrite of dacitic composition has a high phenocryst content and near solidus mineral assemblage. During initial field observations, coarse-grained, crystal-rich fiamme within a pink, interstitial matrix were found within the Fish Canyon Tuff. The fiamme are abundant in some intracaldera horizons, varying in size from a couple of centimeters to decimeters. The largest crystals are feldspars, up to 1 – 2 centimeters in length, with other crystals that are several millimeters in length. The composition of these fiamme appear to be similar to the rest of the ignimbrite, but they have coarser-grained, crystal-rich textures. Initial textural observations lead us to conclude that these fiamme are ejected fragments of magma mush. Further work will include optical and scanning electron microscopy analysis of thin sections, which will allow us to study the relationship between the fiamme matrix and the crystals within it. We will also use energy-dispersive spectrometry to analyze the composition of matrix and crystals in these fiamme. The results will help us understand the origin of these crystal-rich fiamme and understand processes within magma mush for systems that feed crystal-rich supereruptions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Geochemical insights into pre- and post-flank collapse at Antuco Volcano, Southern Volcanic Zone, Chile

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The volcanic products from Antuco volcano are amongst the most isotopically primitive in the Chilean Southern Volcanic Zone. A significant collapse of the western flank occurred 7.1 ka BP removing ~6.4 km^3 of volcanic material, emphasising its hazard potential. We study the chemical compositions and pre-eruptive conditions of pre- and post-collapse products to compare the magmatic source of these two volcanic stages, alongside with the Los Pangues small eruptive centres in the west flank of Antuco volcano (1845 AD). These volcanic products are characterised by their primitive composition, abundant resorbed plagioclase and well-preserved olivine with large melt inclusions, which we interpret as a mafic magma intrusion into the crystal mush of Antuco volcano, driving Hawaiian activity and spatter cone formation. Pre- and post-collapse basalts and basaltic andesites comprise plagioclase and olivine phenocrysts, with rare pyroxenes and inclusions of Cr-spinels in olivine cores. Andesites from both volcanic stages are characterised by the presence of abundant crystal clots of plagioclase, ortho and clinopyroxene, titanomagnetites and rare ilmenite and apatite. Preliminary pre-eruptive conditions show temperature ranges between 1020 and 1120 °C for both pre- and post-collapse units, pressure ranges up to 4 kbar for the post-collapse volcanic products, and oxygen fugacity of ΔNNO-1.3 using one of the pre-collapse samples. Understanding the characteristics of the magmatic source as well the magmatic processes which occur during the ascent path and crustal storage in a volcano which has had a significant flank collapse gives important insights into the causes of this event, aiding future hazard scenarios.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Multiple-phase geobarometry using Rhyolite-MELTS

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The quartz + feldspar Rhyolite-MELTS geobarometer has been applied to rhyolites worldwide and has proved a useful tool for estimating equilibration pressures. However, it is limited to magma saturated in quartz (mostly, rhyolite). Here, we show how the principles of the Rhyolite-MELTS geobarometer can be applied to estimate the saturation pressure of other phases (e.g. pyroxene and magnetite), estimate oxygen fugacity (f_{O2}), and infer the equilibrium mineral assemblage. This extends the usefulness of the Rhyolite-MELTS geobarometer to a broader range of magmatic compositions. We show examples of (1) storage pressure calculations from quartz-absent rhyodacites to rhyolites from Puyehue-Cordón Caulle, Chile; and (2) equilibration between extracted rhyolitic melt compositions and unknown mush mineral assemblages from the Taupō Volcanic Zone, New Zealand. In both cases, we find orthopyroxene + plagioclase ± quartz pressure solutions that agree with independent pressure and f_{O2} estimates. Orthopyroxene saturation is sensitive to f_{O2}, so independent f_{O2} constraint is necessary for calculating plagioclase + orthopyroxene pressures. Alternatively, magnetite is also sensitive to f_{O2} so searching within f_{O2} space for plagioclase + orthopyroxene + magnetite pressures can give both pressure and f_{O2} estimates. These methods are potentially useful for inferring the mineral assemblage a melt composition equilibrated with. Our methods show how Rhyolite-MELTS geobarometry does not need to be limited to three phases. Multiple saturation of a higher number of phases can (1) give further constraints on intensive parameters; (2) yield pressure estimates with smaller uncertainties; and (3) help determine mineral assemblages that equilibrated with a given melt composition.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Complex Magmatic Processes in El Negrillar Monogenetic Field: A Case Study of the Central Andean Volcanic Zone

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Monogenetic volcanic fields, traditionally viewed as simple magmatic systems with direct source-to-surface pathways, are increasingly recognized as complex magmatic systems providing crucial insights into arc magmatism and crustal processes. We present a study of El Negrillar, the largest monogenetic field in the Central Volcanic Zone of the Andes, comprising 51 eruptive centers and 98 lava flows across three clusters (Northern, Central, and Southern). New 40Ar/39Ar dating reveals volcanic activity between 0.982 ± 0.008 and 0.141 ± 0.072 Ma, with synchronous eruptions (within error) throughout the field. The system produced 6.8 km^3 (DRE) of magma, ranging from basaltic andesite to dacite, with systematic compositional variations from SW to NE. The Southern cluster displays primitive olivine-rich characteristics, while the Northern cluster exhibits evolved amphibole-rich compositions. Detailed petrological analysis reveals a complex pre-eruptive history involving fractional crystallization within a main stagnation zone (9-19 km depth) and multiple magmatic processes, including recharge, mixing, and crustal assimilation. Whole-rock major and trace elements and Sr-Nd-Pb isotopic analysis show stronger adakite-like signatures in low-silica members, suggesting magma generation through extremely low degrees of melting of a garnet-rich lower crust source. These signatures resemble those observed in regional back-arc monogenetic volcanism, implying shared aspects of magmatic history. Our findings reveal complex magmatic processes and demonstrate significant structural control on mafic volcanism in the Altiplano-Puna Volcanic Complex, challenging traditional views of monogenetic volcanism in arc settings.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Petrographic insights into recent volcanism in the Carrán – Los Venados Distributed Volcanic Field, Southern Andes (Chile)

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The Carrán-Los Venados Distributed Volcanic Field (CLV), ranked 6th in Chile's active volcano-specific risk, is the largest cluster of minor eruptive centers in the Southern Andes. Formed during the Pleistocene and is still active, the CLV comprises three main units: (1) the basal lavas, forming flows up to 14 km long that fill the Riñinahue and Nilahue valleys; (2) two medium-sized peripheral volcanoes, Los Guindos shield and Media Luna scoria cone, and (3) 72 minor eruptive centers (scoria cones and maars) aligned ENE-WSW, with strombolian and phreatomagmatic eruption styles. This study examines three historical eruptions: the 1907 Riñinahue maar, a phreatomagmatic eruption that formed a pyroclastic ring, with a lava flow filling the crater, and a small pyroclastic cone; the 1955 Carrán maar, a phreatomagmatic eruption with an 8-10 km eruptive column and pyroclastic surges up to 3 km; and the 1979 Mirador strombolian eruption, which produced a scoria cone, fall-out deposits, and two lava flows. These eruptions produced basaltic to basaltic-andesitic rocks (51-55 wt% SiO_2, 7-4 wt% MgO) with typical arc signatures and microporphyric textures, characterized by microphenocrysts of plagioclase, olivine, pyroxene, and oxides, showing disequilibrium textures (such as resorption sieve and reaction rims). Textures indicating complex histories are still under study. Detailed mineral chemistry analyses reveal pre-eruptive conditions and, through comparison with the peripheral volcanoes and the basal lavas, suggest a magmatic storage level at ~12 km depth. These findings improve understanding of the CLV's plumbing system and behavior, contributing to enhanced hazard assessment for future eruptions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Petrologic imaging of magmatic reservoirs: some improvements to clinopyroxene and amphibole barometry

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Barometry based on mineral phases is potentially a powerful tool to investigate the feeding system of active volcanic edifices, however, this approach is severely limited by large uncertainties in existing models (often in the range of 5-10 km depending on models). In this presentation, we will raise a series of key issues that need to be addressed to move forward with mineral barometry: the importance of the calibration database, the difference between accuracy and precision and their use, and the needed feedback between modeling and experimental petrology. We will present two ongoing developments based on amphibole and clinopyroxene barometry, respectively. Barometry based on Al-in amphibole is critically dependent on the associated phases. For amphiboles in equilibrium with plagioclase and biotite in calk-alkaline to mildly alkaline rocks, we calibrated a new barometer (Médard and Le Pennec 2022) with a precision up to 0.8 km and an accuracy around 3 km (depths calculated assuming a granitic crust with a density of 2700 $kg.m^{-3}$). Precision is sufficiently low so that the barometer could be used to investigate the shape of magma reservoirs, giving us a real shot at true petrologic imaging, at least for large silicic eruptions. Clinopyroxene-based barometry can be significantly improved by combining existing calibrations with accurate high-pressure high-temperature experiments run on the composition of interest. Ongoing tests on mildly-alkaline basalts from the Chaîne des Puys volcanic field suggest that in a well-studied volcanic system, accuracy could be decreased to around 3.5 km with a precision of about 0.5 km.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Geological mapping and petrography and mineral geochemistry of Igourdane pluton in the Saghro Massif, eastern Anti-Atlas, Morocco: Preliminary results

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The Saghro massif (eastern Anti-Atlas) exhibits several Ediacaran plutonic bodies, with diverse composition from mafic to felsic. Our investigation concerns the Igourdane granite, located in the eastern part of the Saghro massif in southern Morocco. This study aims to conduct a comprehensive analysis of the Igourdane granite pluton using petrographic, geochemical, along with facies analysis. The Igourdane granite measures approximately 4 km in length and 1 km in width. It shows an elongated shape with a NW-SE orientation. It is bordered by the Oussilkane Charnokite to the south, east, and north, and by the Arharrhiz granite to the west, occasionally it is intruding the lower Ediacaran meta-sedimentary successions of the Saghro Group. The contact between the Saghro Group and the Igourdane granite, exposed to the east, it is characterized by metamorphosed meta-sedimentary formations, which display foliation with magmatic fluid injections. Petrographically, the Igourdane granite features a primary paragenesis dominated by anhedral quartz, K-feldspar, subhedral plagioclase, biotite, and clinopyroxene (CPX), with zircon and apatite as accessory minerals. Secondary minerals include sericite and chlorite. Associated features include aplite and pegmatite dykes (ENE-ESE, 40 cm to 3 m thick) and rare andesitic dykes (N-S, 20 cm to 1.5 m thick). Geochemical EMPA analyses reveal plagioclase zoning and chemical variations in CPX, indicating magmatic differentiation driven by pressure and temperature changes during emplacement. These findings emphasize the Igourdane granite's significance in unraveling the tectono-magmatic complexity of late Ediacaran plutonism in the Saghro massif and its broader implications for the Anti-Atlas magmatic evolution.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Unraveling The Evolution of Silicic Eruptions in a Basaltic Province: Insights From Harrat Khaybar, Western Saudi Arabia

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Some of the major and well-exposed distributed volcanic fields on Earth are on the Arabian Peninsula, locally known as harrats. Harrat Khaybar, Saudi Arabia (ca. 1.7 Ma to Present) is one of the largest and most compositionally diverse Arabian lava field. Its rock compositions range from predominant alkali basalt to trachyte and comendite, where the progression from basalt to rhyolite is attributed to increased magmatic flux, fractional crystallization, crustal assimilation, and/or halogen complexing. We are currently conducting a comprehensive study to evaluate these hypotheses by integrating petrographic observations, whole-rock geochemistry, Sr-Nd-Pb isotopic analyses, and petrogenetic modeling. Interpretation of our new geochemical results to date confirms open-system magmatic processes. Whereas intermediate and silicic rocks show enrichment in light and heavy rare earth elements compared to the basaltic rocks, they mimic the pattern of basalts, except that evolved rocks display a strong Eu negative anomaly. Indices of closed-system fractional crystallization (e.g., Zr/Nb) reveal two linear trends: basalt to trachyte and trachyte to comendite. Sr isotopic compositions of the evolved rocks vary widely ($^{87}Sr/^{86}Sr$ = 0.704 to 0.709) and correlate negatively with Mg#, whereas Pb isotopic compositions exhibit a narrow range ($^{206}Pb/^{204}Pb$ = 18.5 to 18.7) and correlate positively with Mg#. Conversely, Nd isotopes remain relatively constant from basalt to the most evolved rocks (ε_{Nd}= 5.2 to 6.6). These data connote that silicic magmas are the product of assimilation and fractional crystallization processes on basalts. The assimilant is likely the Pan-African granitic basement.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

The life and reactivation of long-dormant PAMS volcanoes: the case of the Late Pleistocene Ciomadul volcano, Romania

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Long-dormant PAMS volcanoes (those with Potentially Active Magma Storage) are defined as those that last erupted >10 ka but have indications that they are still underlain by a magma reservoir with some melt fractions. Therefore, their future reawakening cannot be excluded. Due to their apparent inactivity, these volcanoes get no or less attention and, as such, pose an underrated potential risk. Ciomadul last erupted 30 ka and represents the youngest volcanism in eastern-central Europe. Zircon geochronology revealed prolonged repose periods, even >100 kyr between eruptive phases, but continuous zircon crystallization over >1 Myr. The eruptive products are rather homogeneous, K-dacite in composition and have an adakitic, wet and oxidized character. Integrated textural and compositional studies of multiple mineral phases suggest the existence of a long-lasting felsic mushy magma reservoir within the upper crust underlain by deeper mafic magma storage. Reactivation of the highly crystalline magma body was mostly due to recharge by Sr–Ba-rich mafic magmas. Rejuvenation occurred rapidly, within weeks to months. The eruptions changed from effusive to explosive with the appearance of strongly hydrous mafic magmas. Results of high-resolution magnetotelluric survey indicate conductive anomalies (<10 ohm-m a value indicative of potenial melt presence) in the subvolcanic crustal level. This is interpreted as a quasi-vertical conduit extending from the near surface

to a melt-bearing magma reservoir in the mid-lower crust (depths of 10-25 km), deeper than typically observed for active subduction systems. The presence of magma is also indicated by notable CO_2 gas emission with relatively high He-isotope ratio.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

EPMA geochemical evidence of a long-lived Pleistocene Crystal-Mush in the Northern Andes: geothermobarometric challenges

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We reconstruct the physicochemical conditions of melts in the Pleistocene storage and plumbing system of the Doña Juana Volcanic Complex in southwest Colombia. This complex is a little-known, potentially active polygenetic volcano with dacitic composition, consisting of four major edifices and experiencing long periods of dormancy. By analyzing compositional data from plagioclase, amphibole, pyroxene, and Fe-Ti oxides, along with new and existing whole-rock data from representative eruptive products, we conducted equilibrium tests and geothermobarometry calculations within a well-established stratigraphic, petrographic, and geochronological framework. The textural and geochemical variations in all mineral phases indicate a trans-crustal magmatic system that fueled the Pleistocene eruptions of Doña Juana, with cyclic rejuvenation of a crystal mush following each edifice collapse. The presence of different crystal cargos before magma recharge and eruption is evidenced by (i) the coexistence of equilibrium and disequilibrium textures and variable compositions in all studied crystal species, (ii) felsic cores in antecrysts, (iii) mafic overgrowth rims, and (iv) significantly less differentiated microcrysts compared to meso- and macrocrysts. By integrating multiple mineral-only and mineral-liquid geothermobarometers and conducting thorough textural analyses, we estimate the intensive parameters of the mush–melt interaction zone in the middle crust, offering a preliminary view of the architecture of a trans-crustal magmatic system in a complex tectonic setting within a previously understudied area of the north-Andean volcanic zone.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Constraining aplite-host granodiorite relationships through geochemistry and rhyolite-MELTS geobarometry: Tuolumne Intrusive Complex, Yosemite National Park (California, USA)

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The Tuolumne Intrusive Complex (TIC)–the youngest (90-82 Ma) igneous intrusion in Yosemite National Park–provides insights into magmatic processes. The TIC mostly comprises fine-to-coarse grained granodiorite. Aplite dikes are common within all units of the TIC. Aplites typically form during late-stage plutonism, forming dikes with distinct contacts with the host granodiorite. However, the temperature-pressures at which aplites formed and how they compare to those of host granodiorite at the TIC are not well constrained. Therefore, this study seeks to use rhyolite-MELTS geobarometry to estimate the depth at which aplite dike melts were extracted from host mush, and to test whether it differs from depths of emplacement of host rocks. Additionally, thin sections of aplite dikes and host rocks will be used to investigate the chemical and textural variability across related TIC units. Fifteen aplite samples and five host rock samples were collected in October 2024. The thickness of the aplites ranges between ~1 cm and 30 cm, and they exhibit equigranular, 'sugary' textures. Many TIC aplites display both fine-grained and coarse-grained sections. In some samples, the transition from host rock to aplite is gradational, while in others, it is sharp. Some aplites contain feldspar megacrysts near or within the aplites. Whole-rock major element chemistry will be used to obtain chemical data of six aplite dikes and three granodiorite host rocks, providing critical input for geobarometry. Thin sections will complement thermodynamic simulations and aid in comparing aplites and host rocks from different units, and to evaluate aplite-granodiorite petrogenic relationships.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.7: Petrological characterisation of magma storage

Allocated presentation: Poster

Central Snake River Plain Eruptive Products Are Hot and Dry – Yet Saturated with Zircon: Why?

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Zircon ($ZrSiO_4$) serves as a nearly ubiquitous monitor of conditions in evolved magmatic systems. However, in rocks from exceptionally hot and dry magmatic environments, such as those of the Columbia River -Snake River Plain-Yellowstone province, an unexpected abundance of zircon is observed despite high magmatic temperatures and low Zr contents. These conditions theoretically favor zircon undersaturation, raising the question of how significant zircon crystallization could occur in such chemically and thermally unfavorable environments. Addressing this paradox is the primary focus of this study. We present new time-temperature estimates derived from zircon U-Pb geochronology, mineral thermometry and bulk rock/glass thermodynamic modeling to reconstruct the final stages of the thermal history of one of the youngest and hottest (>900°C, two-pyroxene and ilm-mgt thermometry) eruptions in the Central Snake River Plain: the Castleford Crossing ignimbrite. These results are integrated within a broader context, incorporating data from three older ignimbrites in the same stratigraphic profile which are intensely welded and commonly rheomorphic. Furthermore, we explore theoretical considerations on the role of (post-)eruptive emplacement conditions, to align the high temperature mineral record along with zircon saturation under these extreme conditions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Talk [Invited]

The compressibility of the Svartsengi magma domain: lessons learned from comparison of volumes of inflation-deflation and volumes of dikes and lavas during the Sundhnúkur crater row rifting episode 2023 to present

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Rifting events at the Sundhnúkur crater row, Iceland, beginning in 2023, have drained magma from a magma domain at ~4-5 km depth, where magma accumulates between events. Geodetic observations and modelling give information on deflation source volume contraction, as well as volumes of dikes (~156 Mm^3 and ~182 Mm^3 at end of 2024, respectively). Volume of eruptive products (lavas) mapped by photogrammetry is ~217 Mm^3 at end of 2024. Constraints on the compressibility of the magma domain comes from the ratio between volume change of the deflation source and the DRE volume of the extracted material. Assuming DRE volume of lava extruded during deflation is 0.8 of measured total lava volume and geodetically imaged dike volume corresponds to DRE volume, we preliminary infer the ratio to be in the range 1.3-4.2, comparable to that reported in studies of basaltic systems. The ratio depends on the shape of the magma domain, the shear modules of host rock and the compressibility of material in the domain. If the domain is approximated as an horizontal spheroid with horizontal semiaxes of 4 km and 1.5 km, half-thickness of 1.5 km, and crustal shear modulus is 10 GPa, then the inferred compressibility of material in the domain is ~0.03 - 0.3 GPa^{-1}. Compressibility of the erupted basaltic magma at depth inferred from petrochemical analysis is within this range, showing the difference in volume change of the magma domain and volume of extruded material and dikes can be explained by the effects of magma domain compressibility.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Talk

Crustal thickening and doming induced by the emplacement of volcanic plumbing systems: case studies at back-arc volcanoes in the Neuquén Basin, Argentina

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Volcanic edifices in textbooks are typically represented as local accumulations of volcanic products generally building up from a near flat substratum. In this contribution, we present three volcanoes case studies and show that their substratum has been systematically uplifted by crustal doming. These case studies formed in the compressional back-arc tectonic setting of the Neuquén Basin, Argentina. These volcanic complexes built upon, and their shallow plumbing systems were emplaced into, the Mesozoic sedimentary strata of the Neuquén Basin. Borehole data and 3-dimensional seismic data acquired for hydrocarbon exploration show that the strata of the Mesozoic substratum underneath each volcanic complex exhibits a large, gentle domal structure of 500 to 1000 metres amplitude. The domal structures correlate in position and dimension with those of the volcanoes, which consist of a thin cover of volcanic products coating the underlying crustal dome. The volcanoes also show evidence of lower amplitude localized doming around individual and nested shallow intrusions. Our study suggests that the injection of volcanic plumbing systems in back-arc settings contributes to crustal thickening and doming of the Earth's surface. Such doming likely locally affects regional stresses, which may impact magma transport in the shallow crust and control the emplacement of radial dyke swarms, shallower sill intrusions, and enhance transport of magma to the surface. In general, our study highlights the effects of volcanic plumbing systems on the structure and stress in the Earth's crust, and the links from the deeper to the shallower parts of the system.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Talk

Melting of hydrothermal system: Petrology of glassy-like bombs in 1895 eruption of Zao Volcano, NE Japan

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Glassy-like bombs of 1895 hydrothermal phreato-magmatic eruption of Zao Volcano were petrologically examined. The 1895 eruption products are mainly volcanic breccia composed of mainly altered blocks of older lavas with minor amount of juvenile scoria and glassy-like bombs in a hydrothermally altered whitish gray colored matrix. The scoria is ol bg. cpx opx andesite (ca. 57–58 % in silica content), showing hyalo-ophitic groundmass texture. The glassy-like bombs have cores of dense andesite (<ca. 20 cm). The glassy-like parts cover and sometimes intrude into the core andesites. The core andesites are the same as the juvenile scoria in composition. The glassy-like parts are less porphyritic two px andesite to dacite, having glassy-like groundmass, and are sometimes vesiculated. Disaggregated andesites are observed, that indicates most phenocrysts would derive from core andesites. The glassy-like groundmass is divided into color-less, light brownish colored, and brownish colored parts. These three parts are composed of glass, glass-microlite (plagioclase, cordierite, and osumilite) mixture, and glass-nanolite (almino-silicate) mixture, respectively. The whole rock compositions of the glassy-like bombs are trachyandesitic to trachytic in composition (59–68% in silica content; K and Al-rich, Ca-poor) that cannot be explained by fractional crystallization nor melt accumulation from the andesitic composition of juvenile scoria. K and Al-rich character indicates the melting of hydrothermally altered rocks. It is probable that some parts of the altered rocks in the hydrothermal system were melted by the injection of the andesitic magma. Thereafter the melts assimilated the solidified andesites and erupted as the glassy-like bombs.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Talk

Magma storage, evolution and degassing at Mombacho (Nicaragua): new insights to decipher the current state of activity of a long dormant volcano

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The Mombacho is a basaltic-andesitic stratovolcano of Nicaraguan Quaternary volcanic chain. As no eruption has been recorded at Mombacho, no information is available on the depth of potential magma storage zones, nor on the evolution of ascending magmatic fluids. However, this information is urgently needed given the current state of the volcano, which is showing signs of unrest. To acquire this knowledge, melt inclusions and pyroxene crystals in various Mombacho tephras were analysed, along with the volcanic gases emitted by crater fumaroles. The major element compositions of the melt inclusions support, to a first order, a magmatic evolution controlled by the fractional crystallisation of olivine, pyroxene, plagioclase and titanomagnetite crystals. However, the compositional variability of the most basic samples can only be explained by a source heterogeneity. Additional trace elements analyses agree with this hypothesis but seem to highlight a migration of the most mobile elements with an aqueous phase. The composition of the clinopyroxene crystals and the H_2O and CO_2 contents of the melt inclusions reveal the presence of a complex main storage zone between 0,75 and 2,5 kbar. Degassing modelling also supports this architecture and indicates that the gases sampled in 2024 in the Mombacho fumarole come from depths similar to this large storage zone. For their part, the 2024 fumarole temperature and gas composition are similar to those sampled during the last twenty years, highlighting the stability of the degassing and therefore of the underlying magmatic system.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Talk

Subsurface lateral magma propagation from Nyiragongo volcano (DRC): an interplay between rifting-induced extension and edifice loading

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In rift zones, it is common to observe lateral propagation of magma characterized by vertical dykes developing parallel to the rift direction. Depending on the competition between vertical and lateral magma migration, these dykes either feed an eruption or not. In this context, the topography that includes the load of the edifice acts against the rise of magma and favors lateral and radial migration away from the edifice. Here, we study the combined effect of the rifting-induced extension and the topographic loading of the Nyiragongo volcano located in the western branch of the East African Rift. Using analytical and numerical models, we show that the path of a dyke originating from the volcanic edifice is first influenced by the load of the volcano, leading to a radial propagation. Beyond 5 km, however, the rift-induced extensional stress field dominates leading to a north-south propagation towards Lake Kivu, consistently with the path of the magma inferred by geodetic and seismic studies during the last two eruptions of the Nyiragongo volcano. We then determine the direction of propagation within the propagation plane as a function of the direction of the maximum stress gradient, a method which we have validated using analogue experiments. It shows that the lateral propagation over more than 20 km is controlled by depth-dependent extension and reduced magma buoyancy and, to a lesser extent, the downslope towards Lake Kivu and the slight increase in rift extension towards the south.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Talk

Tracking velocity changes of the 2024 Kīlauea East Rift Zone eruption and preceding intrusions with ambient noise interferometry

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The Kīlauea volcanic system on the Island of Hawaiʻi is renowned for its frequent eruptive activity, including summit crater and rift zone eruptions. In September 2024, Kīlauea experienced its first eruption in five years in the Middle East Rift Zone (MERZ) near Nāpau Crater, marking a shift from recent eruptions localized at the summit or the Southwest Rift Zone. This eruption, along with the preceding intrusive activity, was captured by a dense seismic nodal network comprising of 116 stations distributed over a 30×60 km area in the East Rift Zone (ERZ). Using ambient noise interferometry, we investigate magma-tectonic interactions by monitoring seismic velocity variations (dv/v) across space and time. These variations, which are influenced by both internal factors (magmatic and tectonic activity) and external forces (e.g., precipitation), are contextualized using data from the Hawaiian Volcano Observatory's permanent network of tiltmeters, GPS stations, and precipitation sensors. Initial results show a velocity decrease of up to 1% during the July 2024 intrusion event, correlating with increased seismicity and tilt changes both at the summit and in the MERZ. By incorporating volumetric strain modeling, we discuss the depth of the deformation source responsible for these changes, providing new insights into the processes driving the eruption. This study highlights how the integration of various geophysical observations can improve the understanding of volcanic precursors and magma dynamics and demonstrates the potential of dense seismic networks for volcano monitoring.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Talk

Modeling Magma Recharge Dynamics during the 2016 Nevados de Chillán Eruption: Insights from a Two-Chamber Interaction System through Petrology and Geodesy

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The Nevados de Chillán volcanic complex in southern Chile experienced a six-year eruption. During the first three years, phreatic and phreato-magmatic activity occurred without surface deformation. In June 2019, an effusive phase began, marked by an uplift episode. This study analyzes surface displacements from 2015 to 2022 using InSAR and GNSS data, integrated with petrological, geochemical, geophysical, and field observations, proposing that deformation was driven by magma recharge between two reservoirs beneath the volcano. Our model, combining analytical and boundary element methods, accounts for reservoir geometries and topographic effects on surface displacements. Results indicate a shallow elongated reservoir (5.8 km depth) connected to a deeper sill-type reservoir (15 km depth) via a magma-filled conduit. An initial small magmatic intrusion likely activated the system by overheating the hydrothermal system, explaining the lack of deformation during the phreatic phase, followed by magma mobilization causing minor subsidence during the phreato-magmatic phase. In June 2019, a larger magma intrusion triggered uplift, decaying exponentially over three years, driven by a constant magma influx of 0.016 km^3/year into the deeper reservoir. This dynamic recharge model explains mafic enclaves in erupted dacites and integrates geophysical, petrological, and geochemical observations. It offers insights into eruptions and uplift episodes in volcanoes with interconnected magma chambers, advancing our understanding of pre-, co-, and post-eruptive magma recharge processes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Mount Edgecumbe (L'úx Shaa) volcano magma storage conditions

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Mount Edgecumbe is a stratovolcano located in Southeast Alaska which last erupted in the mid-Holocene. A new magma intrusion was observed in 2018 resulting in increased seismicity and ground deformation. This study will provide petrologic and experiment-based data on the magma plumbing system at this volcano using late Pleistocene dacite, rhyolite, and basalt samples. Temperature estimates from Fe-Ti oxide equilibrium pairs yield 922 to 975 °C in the dacite and 866 to 928 °C in the rhyolite, with fO_2 NNO 0.5 to -0.9 log units in the dacite. FTIR analyses returned ~2.8 wt.% H2O in pyroxene-hosted melt inclusions from the rhyolite and ~1 wt.% H2O in olivine-hosted inclusions from the basalt. The experiments will utilize dacite starting material at pressures ranging from 75 to 300 MPa and temperatures between 800 to 1100 °C at water-saturated conditions. For temperatures below 900 °C, we will use Waspaloy cold seal pressure vessels and above 900 °C we will use TZM and MHC alloy pressure vessels. Waspaloy runs will be buffered at ~ NNO+0.5 log units using a nickel filler rod. TZM/MHC runs will be buffered by adding ~2.5 bars CH4 gas to buffer hydrogen diffusion, monitored with a separate capsule containing buffer compounds. The results from these experiments will be used along with Rhyolite-MELTS modelling to replicate the mineral assemblages and abundances in the natural sample. Once the experimental study is complete, our petrology-based model for magma storage at Mount Edgecumbe will provide context for recent and potentially future geophysical unrest.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Magma mixing in a dacitic plumbing system of Citlaltépetl volcano around ~4 kyr BP, eastern Trans-Mexican Volcanic Belt

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Magma mixing is a common mechanism at the active Citlaltépetl volcano (5,650 above sea level), located in the eastern Trans-Mexican Volcanic Belt. We document two explosive eruptions (Avalos ~4 kyr BP and Jamapa <5 kyr BP) that generated pyroclastic density currents. The Jamapa Vulcanian-type eruption generated a scoria flow deposit, constituted by andesitic scoria (58 wt. % of SiO_2), dacitic pumice (63 wt. % of SiO_2), and banded scoriaceous fragments. The mineral assemblage is made of plag + opx + cpx + amph + /- Fe-Ti oxides in different proportions with disequilibrium textures. Plagioclase and matrix glass compositions are heterogeneous suggesting mixing between andesitic and dacitic magmas. Whereas Avalos is related to a dome-destruction event that produced a block-and-ash flow deposit of homogeneous dacitic composition (63-64 wt. % of SiO_2). The mineral assemblage is made of plag + cpx + opx + amph +/- Fe-Ti oxides. However, plagioclase and matrix glass compositions are also heterogeneous suggesting a mixing between two magmas. Pressure and temperature estimations for both eruptions point to a relatively shallow dacitic reservoir (~190 MPa and ~880°C) continuously rejuvenated by hotter mafic melts coming from deeper reservoirs (~390 MPa and ~980ºC). The Jamapa event likely occurred shortly after the contact between the mafic and felsic magmas, whereas the Avalos eruption occurred after a longer period of time since the mixing event. Our results suggest the presence of a shallower felsic magma reservoir feeded by deeper mafic magmas stored ≥ 14 km below Citlaltépetl volcano.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Evaluating Second Boiling as a Driver of Overpressure and Surface Deformation in Volcanic Systems

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Volatile exsolution during magma crystallization, commonly referred to as second boiling, is a long-recognized mechanism for overpressurizing subvolcanic magma reservoirs through the expansion of a free fluid phase. Recent petrological studies have highlighted the role of late-stage volatile saturation in the lead-up to explosive eruptions. Thermodynamic calculations indicate that this process can generate overpressures on the order of tens of megapascals, potentially triggering volcanic eruptions. However, these models often assume a uniform temperature-time cooling trajectory for magmatic systems, overlooking the complexity of whole-reservoir cooling dynamics. Here we investigate the interplay between second boiling and magma reservoir evolution, emphasizing how cooling rates and viscous relaxation influence overpressure development. We introduce a novel thermodynamic-thermal coupling framework that tracks the pressurization and deformation history of crustal-scale magma reservoirs. This approach incorporates magma and chamber compressibility, volatile redissolution upon pressurization, and varying magmatic fluxes and intrusion depths. The results reveal that compositional and thermal factors, including felsic crust and high-temperature viscoelastic aureoles, serve as first-order controls that favor the relaxation of overpressures rather than their generation over time. We apply our model to the 12.9 ka VEI-6 Laacher See eruption (Eifel Volcanic Field, Germany), which exhibits evidence of late-stage volatile saturation. Integrating zircon-based magma flux estimates, thermometry, thermodynamic and thermo-mechanical models, we assess whether volatile accumulation could have triggered the eruption and whether surface deformation patterns might have provided early warning.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Dike propagation and surface faulting around Fentale Volcanic Complex, Northern Main Ethiopian Rift

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Extensional stresses favour dike intrusions, posing significant hazards to local populations. However, geodetic measurements of active dike intrusions in thick continental crust are relatively rare. A dike intrusion in 2015, and more recently in 2024–2025, occurred northeast of Fentale in the Main Ethiopian Rift. Unusually, both intrusions opened over several weeks, suggesting a different rheology to the basaltic dike intrusions in Afar and Iceland. We present new, high-resolution COSMO-SkyMed and Sentinel-1 InSAR timeseries of the September-October 2024 dike intrusion. A preliminary kinematic model suggests that the InSAR displacement patterns can be explained by a ~7 km long dike with a maximum opening of ~2 m at ~5 km depth. The dike opening was accompanied by graben subsidence of at least 20 cm accommodated by multiple surface-rupturing normal faults. To investigate the mechanical relationship between dike opening and fault slip, we constructed a boundary element model featuring frictional fault surfaces within an extensional stress regime, where the faults are primed for slip. We then introduce a pressurized dike, which induces normal-sense slip along the faults. We show that fault slip occurred above the dike rather than ahead of it. Our high-resolution data provides new constraints on dike behaviour, contributing to a broader understanding of fault-dike interactions in active rift settings. Further work will investigate the role of tectonic stresses, magma overpressure and topographic load on the dike sequence, looking to forecast the location of the next dike and if it will lead to eruption. Activity is ongoing in 2025.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Volcano-Tectonic Modelling: The Migration of Magmatic Reservoirs

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Benoit Taisne,

Luca Dal Zilio *Earth Observatory Singapore, Nanyang Technological University, Singapore, Singapore.* Arc-related magmatic reservoirs are thought to migrate in response to pre-, syn-, and post-thrust faulting, becoming increasingly vertically aligned due to enhanced edifice loading. This study aims to investigate the thermodynamic and mechanical co-evolution of magmatic plumbing systems and crustal structures, as well as their interactions with local and regional stress fields over million-year timescales. Our two- and three-dimensional numerical modelling approaches involve varying the onset and pre-existence of crustal structures alongside single and episodic magmatic intrusions into a visco-elasto-plastic crust. We simulate plutonic geochemical evolution and long-lived cold storage conditions through the parallelised computation of thermodynamic phase diagrams on high-performance computational infrastructures. The geochemical, thermodynamic, and kinematic structures of volcanic plumbing systems, from mantle to surface, remain a topic of active inquiry. This work seeks to resolve aspects of reservoir migration due to compressional back-arc volcano-tectonic interactions and provide a suite of plumbing system reference models for geophysical and petrological interpretations. By integrating magma dynamics with tectonic processes over geological timescales, our research aims to advance the understanding of the connectedness of plutonic and volcanic systems in arc environments, contributing to improved insights into the timing and dynamics of volcanic unrest.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Impact of topography and water load on magma propagation modelling

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Coastal and marine volcanoes exhibit complex topographies, much of which lies below sea level, making it challenging to fully assess the interplay between topography and magma propagation. This interaction is vital for understanding volcanic hazards such as dike-induced eruptions and slope instability. Notably, the interplay between topography and stress fields directly links to slope stability, emphasizing the need for integrated analyses when assessing volcanic hazards. When calculating the contribution of gravitational loading to the stress field within and beneath volcanoes, traditional models of dike propagation often simplify volcanic edifices as surface loads, thus neglecting the nuanced effects of realistic topography on stress distribution and slope stability. To address this limitation, we developed a 2D Boundary Element Model for viscous-fluid-filled cracks that incorporates a discretized free surface. This allows for the integration of detailed topographies, enabling dynamic interactions between topographic features and magma pathways. Using COMSOL Multiphysics, we calculate stress fields for four scenarios: (1) a flat surface with a surface load, (2) a symmetric and (3) an asymmetric volcanic edifice, and (4) an asymmetric edifice with an additional water load, with gravity applied in each scenario. These case studies aim to highlight the influence of topography and water loads on magma propagation. Preliminary analyses suggest that incorporating realistic topography can substantially modify magma pathways, velocities and dike shapes, and the associated stress and displacement fields. These findings have important implications for understanding magma behavior in marine volcanic systems and for evaluating the stability of volcanic edifices.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Nested eruptive pattern of multi-volcanisms based on the historical eruption records in Kirishima volcano, Kyushu, Japan

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Arc volcanoes pose some of the greatest volcanic risks to society due to their frequent explosive eruptions. Preparing for such events requires knowledge of past eruptive behavior gathered from the geological record. However, it can be difficult to decipher the exact timing and vent locations for recent eruptions without corresponding observational records. For this study, we have integrated geological data with newly reviewed historical eruption records for the active Kirishima volcano in Kyushu, Japan, that has erupted repeatedly during the historical period. We used three historical documents to examine the presence or absence of eruptions and identify their source vents since the 8th century. The results suggest that a magmatic eruption occurred at Ioyama in the late 16th century, based on the historical record and a previously published ^{14}C age. Another record indicates that Shinmoedake had been quiet prior to 1656 CE. In addition, the 14th and 15th centuries were periods of considerable quiescence, with a lack of eruption records for the entire Kirishima volcano during that time. These results indicate that the activity mode of Kirishima volcano changed from a single-volcano phase at Ohachi from the 8th to 13th century to a multi-volcano phase after the 16th century. During the multi-volcano phase of activity, eruption transitions from Ohachi to Shinmoedake/Ebinokogen-Ioyama occurred on decadal timescales. Transitions from single-volcano to multi-volcano phases at Kirishima volcano and other broad stratovolcanoes can occur over millenia, but may also undergo relatively rapid transitions on decadal timescales or within eruption events.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

From Curtains of Fire to Focused Flow: Experimental Insights into Conduit Evolution in Volcanic Fissures

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Thermal feedback processes between dikes and crustal rocks influence magma transport, eruption dynamics and the longevity of volcanic conduits. In fissures, variations in width and crustal rock temperature can lead to conduits of focused flow that sustain eruptions, and domains of slower viscous flow that seal them. In modern eruptions this is seen as a shift from a curtain-of-fire behaviour, to focused eruptive sites that prevail and intensify. Better understanding why, how and when this transition occurs can yield improved risk reduction in an active eruption's early stages. To do this, we perform experiments with an artificial fissure, where warm molten wax (25°C) is injected into a cold-sided slot (5°C) with a preset shape. The setup's flexibility allows adjustments to fissure shape, width and temperature, simulating conditions that affect wax solidification, flow diversion, and conduit or blockage formation. Upon initial ascent, a layer of insulating solid wax forms against the cold wall, and its accretion produces narrower, colder domains from which flow is diverted into wider, warmer active conduits. Moreover, wax flow responds quickly to geometric obstacles, where unstable trails of slow-flowing wax develop downflow (above the obstacle), shifting laterally and generally increasing in surface area through an experiment. These experiments illustrate thermo-rheological processes in volcanic systems, where thermal mechanisms influence the development of stable conduits or blockages. The unstable viscous trails formed downflow of obstacles indicate instabilities generated in the laminar flow, and may play a role in the failure of fissure eruptions to regularly localize.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Modelling Stress and Strain Rates of Dynamic Magma Mush Reservoirs: Insights into Reservoir Stability and Failure.

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Volcanoes can enter phases of unrest that may or may not culminate in an eruption. Assessing the stability of magma reservoirs is essential for understanding what differentiates these outcomes. Over the last decades, magma reservoir modelling has been shifting from simple, static models of melt-filled magma chambers to dynamic magma-mush reservoirs (DMMRs), where magma is stored in and moves through a permeable crystal matrix. DMMRs can be approached as poroelastic reservoirs, where failure within or at the reservoir boundary is likely influenced by strain rates from magma migration/accumulation, and the state of stress in the surrounding rocks and elastic matrix. Determining the latter requires consideration of the medium's response to gravity. Recent progress in numerical modelling of DMMRs has provided new insights into the dynamic processes of magma injection and withdrawal. However, most models lack detailed analysis of reservoir failure and often overlook the role of gravity. We address these aspects in our study. Specifically, we examine the steady state of stress within and around a DMMR arising from the gravitational force and load of the surrounding rocks. Then, using Finite-Element numerical models, we study the evolution of strain rates and stress patterns in both the reservoir and the host rocks and the deformation over time and space when magma is supplied to the reservoir. We consider mush reservoirs of various geometries and different assumptions on the initial state of stress and pore pressure of the system, discussing the locations and timing where reservoir failure may become more likely.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

The interplay of surface evolution, shallow magmatism, a large hydrothermal system, and hazards following the 2011-12 Cordon Caulle Eruption

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The Puyehue-Cordón Caulle Volcanic Complex has been one of the most active silicic volcanic centers globally in the last century with three large silicic eruption that produced both extensive lavas and Plinian fall deposits. The most recent 2011-12 eruption also produced a shallow intrusion (approximately 200 m below the surface) that uplifted the landscape by hundreds of meters, modified the conduit of the eruption modulating the explosive-effusive transition, and enhanced an already vigorous near-surface hydrothermal system. The processes of intrusion emplacement and the continued changes in the subsurface and the landscapes are the focus of an ongoing multi-national, multi-disciplinary study named the “Caulle Hazards and their Interplay during Laccolith Continuous Observations” (CHILCO). By integrating data from petrology, volcanology, water chemistry, geodesy, gravity with structural measurements, magnetic, landscape and thermal surveys we develop refined models for the emplacement of the shallow intrusion and its temporal and spatial evolution both in the sub-surface and mass redistributions on the surface and its surroundings. Furthermore, these studies inform potential evolving and emerging hazards related to this over-steepened landscape that remains underlain by the voluminous, actively deforming magmatic system, which fed the past three eruptions (and likely several more in Holocene times). Here we summarize the latest findings of our multi-year observational array that started in 2022 and invite additional collaborative research opportunities that complement our ongoing investigations.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Hydraulically linked reservoirs simultaneously fed the 1975–1984 Krafla Fires eruptions

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The 1975–1984 Krafla Fires in northeast Iceland was the first plate-boundary rifting episode to be tracked using seismic and geodetic monitoring. We present a detailed petrologic and geochemical study of all Krafla Fires eruptions. New whole-rock, matrix glass and mineral analyses show a clear compositional bimodality in the erupted magmas that persisted across the episode, with evolved quartz tholeiite (MgO = 5.8 ± 0.2 wt.%) erupted inside the caldera and more primitive olivine tholeiite (MgO = 7.3 ± 0.8 wt.%) erupted north of the caldera. Barometric calculations indicate tapping of these magmas from distinct reservoirs: a primitive lower-crustal reservoir at ~14–19 km depth, and a more evolved reservoir at ~7–9 km depth beneath the caldera. These reservoirs were tapped simultaneously in several of the eruptions, and in three events the two magma types mixed near the northern caldera margin. Clinopyroxene rims on gabbroic nodules from primitive September 1984 lavas record lower crustal pressures, while diffusion models suggest that these rims grew up to within a few months before eruption. Transcrustal ascent of the primitive magma thus occurred over timescales much shorter than eruptive reposes. These observations are inconsistent with the view that the eruptions were entirely fed by lateral magma outflow from the shallow reservoir. They instead require some decoupling of the flow paths of the two magmas: the primitive magma either bypassed the subcaldera reservoir laterally or ascended vertically beneath the northern vents. The two reservoirs nonetheless shared a hydraulic connection and jointly responded to rifting.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Towards a better modelling of deformation caused by magmatic mushes: Benchmarking a Computational Fluid Dynamics-Discrete Element Methods (CFD-DEM) models with analogue experiments

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Observed deformation at active volcanoes results from complex interactions and coupling between the magma and the host rock. Fracturing of the crust during its deformation can make the pattern of surface displacement even more complex. Building models taking into account both the fluid and the solid phases and their interactions is a crucial next step to better understand the deformation observed in natural systems. We use the software MFiX (Multiphase Flow with Interphase eXchanges) which considers two phases: a fluid phase simulated with Computational Fluid Dynamics (CFD), and a solid phase composed of spherical particles computed using the Discrete Element Methods (DEM) method. In DEM, particles can be bonded together to simulate an elastic solid. Bonds can break at any time step, such that actual fractures can develop during the simulations. We present here the final step of the benchmarking of the newly implemented bonds in MFiX. We are testing the coupling between the fluid phase and the bonded packing of particle by reproducing two sets of analogue experiments. In these experiments, a spherical cavity was created in a block of gelatin and then inflated at constant flux until fluid-filled fractures started to propagate away from it. In the first set of experiments, the fluid buoyancy was varied, and in the second set the fluid viscosity was varied. We show that this new model has the potential to model the magma as a fluid phase and couple it to the elastic and brittle deformation of the surrounding rock.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Diversity of primary magma types and their cyclic temporal changes beneath an island arc volcano: Geology and petrology of Akita-Komagatake volcano, NE Japan

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Akita-Komagatake volcano has been active since 15 ka after a long period of dormancy and has erupted two magma types with different Sr-Nd-Pb isotope ratios. One has SiO_2 = 51-63 % and $^{87}Sr/^{86}Sr$ = 0.7041-0.7043 (high-Sr type) and the other has SiO_2 = 53-60 % and $^{87}Sr/^{86}Sr$=0.7039-0.7040 (low-Sr type). In both types, the isotopic ratios change gradually with increasing SiO_2 content, and the ratios of incompatible elements such as Ba/K and Zr/K are not constant. This suggests that the compositional variation of each magma type was not formed by simple fractional crystallization, but by the AFC process of the primary basaltic magma. In addition, these two magma types show distinct trends in SiO_2 vs. isotope ratio diagrams, indicating that the primary basaltic magma and associated crustal materials were different between the two magma types. Each magma type was active at different stages of activity without a relatively long dormant period. The high-Sr type during 15 - 13 ka, the low-Sr type during 13 - 9 ka, and the high-Sr type again from 9 ka. In the 20th century, although the high-Sr type was still active in the CE 1932 eruption, the magma type changed to the low-Sr type in the CE 1970 eruption. It is suggested that two primary basaltic magma types with different source mantle originated sequentially and each ascended respectively to form a magma plumbing system beneath the volcano. The cycle from high to low-Sr type has been repeated twice in 15,000 years.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Influence of crustal heterogeneities on stress fields and surface deformation induced by magmatic intrusions: insights from the Andes

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In orogenic regions like the Andean Cordillera, volcanic edifices often form on a crust composed of dipping and mechanically heterogeneous rock layers. On this basis, magmatic intrusions and magma reservoirs are emplaced and propagate through a crust which is far from homogeneous or isotropic, assumptions frequently used in the study of volcanic stress fields and deformation. This study investigates how crustal heterogeneities influence the stress field and surface deformation induced by magmatic emplacement and propagation. We combined field observations with Finite Element Method (FEM) models and analogue experiments using gelatine and water as crust and magma analogues, respectively. Our results demonstrate that dipping heterogeneous rock layers can significantly modify stress field induced by magmatic intrusions, altering intrusion geometries and the potential location of new eruptive vents. Tensile stress magnitudes at the surface were amplified by up to 40 times, and the location of maximum stress locations were shifted observed by as much as 1.4 km compared to a homogeneous crust. Additionally, crustal heterogeneities generated asymmetrical surface deformation profiles for vertically propagating dykes, resembling the patterns observed in inclined sheets within a homogeneous crust. These findings emphasize the importance of accurately characterizing subsurface geology to improve interpretations of volcano dynamics during unrest to enhance monitoring efforts.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Megadyke propagation down dynamic topography

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Magmatic dykes that extend laterally for hundreds to thousands of kilometres are known as megadykes. These are fundamental features of both Earth and Venus's crust whose formation mechanisms remain poorly understood. Megadyke structures typically form swarms that originate from a common source and that propagate laterally without eruption. The challenge lies in explaining why dykes eventually terminate with a characteristic length in a given swarm. Here we show that megadyke propagation is driven by the dynamic topography (and gravitational potential energy, GPE) created by underlying mantle plumes, with dyke length controlled by gradients in gravitational potential energy associated with domal uplift. Using a mathematical model of fluid-driven fracture that incorporates magma solidification and turbulent flow dynamics, we demonstrate that dykes perched at their level of neutral buoyancy can propagate laterally to distances comparable to or exceeding the size of the underlying plume head. Moreover, we show that such dykes require lower source pressures than previously thought. The GPE mechanism explains both the characteristic lengths of megadyke swarms. It also explains their variable extent:small changes in source pressure can significantly affect propagation distance. Our findings provide a new framework for understanding the formation of these massive geological structures and suggest that plume-induced dynamic topography may play a crucial role in controlling radial dyke systems within Earth's crust.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Conceptual models of volcanic systems to support volcano monitoring in Aotearoa New Zealand

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Conceptual models of volcanoes are crucial resources for interpreting volcano monitoring data, creating eruption forecasting tools, and assessing long-term hazards. They can be formed through the synthesis of various datasets (e.g., petrology, geophysics, geochemistry) pertaining to both past eruptions and the current status of the volcano. Commonly, conceptual models can be represented as various cross-section interpretations of the subsurface volcanic system with annotations related to the different processes that might be occurring. The volcanology community across Te Pū Ao GNS Science and universities in Aotearoa New Zealand have thus generated and updated conceptual models to aid in the interpretation of volcano monitoring data by the GeoNet Volcano Monitoring Group. To date, we have created six conceptual models: Ruapehu, Whakaari (White Island), Okataina, Taupō, Taranaki, and Rangitahua (Raoul Island) volcanoes; models for Tongariro/Ngauruhoe and the Auckland Volcanic Field will be developed in the near future. Our conceptual model creation methodology typically involves a workshop synthesising information on a particular volcanic system through presentations by subject matter experts followed by feedback on the derived model. Once in place, prompts are made to review the conceptual model during weekly volcano monitoring meetings to help with data interpretation during unrest. Ongoing review of our processes includes investigating the balance between including the most up-to-date (but potentially unpublished) datasets, the frequency of updates, and model accessibility. We are interested in discussing and learning how other groups develop, maintain, and use their conceptual models in volcano monitoring worldwide!

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Magmatic overpressure and reservoir rupture conditions of the Nisida eruption (3.98 ka): implications for magma-driven unrests at Campi Flegrei caldera

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Volcanic eruptions occur when magma-filled fractures break through the Earth's crust reaching the surface. Reconstructing the geometry of feeder dykes can provide insights into physical parameters such as overpressure and inform about reservoir rupture conditions, which are pivotal for volcano monitoring purposes. This is extremely relevant in highly urbanized volcanic areas such as the Campi Flegrei caldera (southern Italy), which experienced several volcanic unrest in the last decades. This work focuses on the low-moderate magnitude Nisida fissure eruption (3.98 ka), which precedes the only historical eruption in 1538 CE. We combined new structural evidence associated with dyke-induced deformation with existing petrological, geochemical and geophysical data. Based on suitable crustal and magma properties, and the geometry of the feeder dyke, we estimate the dyke overpressure. On these grounds we evaluate the volume and storage depth of the magma feeding chamber, yielding values consistent with those derived from petrologic constraints. Therefore, we could quantify the minimum volume, i.e. the excess pressure, necessary to rupture the reservoir and promote dyke initiation, which in turn, eventually leads to propagation and eruption. Hence, for the first time, we suggest a threshold for reservoir rupture at Campi Flegrei, linked to geodetically detectable magma movements that may anticipate impending eruptions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Insights into Surface Deformation Patterns During Volcanic Unrest

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Several subsurface processes associated with the storage and transport of magma and/or supercritical fluids contribute to surface deformation at active volcanoes. The complexity of these processes complicates the interpretation of the unrest mechanism (e.g., magma vs. hydrothermal vs. tectonic) and deciphering the subsurface conditions from monitored signals presents a further challenge. Here, we explore various processes that likely occur in the shallow subsurface during volcanic unrest, either individually or in combination, and analyze their relative contribution to surface deformation through physics-based numerical modeling. We designed time-dependent Finite Element Method (FEM) numerical models to investigate how the elastic deformation of the shallow crust produced by a pressurized magma chamber compares to that caused by thermo-mechanical expansion and poroelastic effects due to the flow of supercritical CO_2 and H_2O. Our models show that magma chamber pressurization, thermal expansion, and poroelasticity can significantly impact ground deformation. These effects vary based on the source depth, crustal properties and timescales. On short timescales (days) in homogeneous segments, a 0.2 MPa increase in magma chamber pressurization causes twice the surface deformation compared to an equivalent magma chamber pressure rise due to poroelasticity. The thermal expansion associated with 10 °C increase leads to ten times more cumulative deformation than short-term magma pressurization, and over longer periods (1-5 years), thermal expansion can be significant. This research provides valuable insights into subsurface processes and improves volcanic unrest signal interpretation, aiding in better forecasting and community safety.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Fast ductile rock deformation accommodating dyke emplacement in the middle crust

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Growth of magmatic sheet intrusions is generally assumed to occur through initial tensile fracturing and elastic bending of the host rock. In addition, most models assume that rates of dyke emplacement are too fast to be accommodated by ductile flow of the host rock, even at mid-crustal levels. There is, however, increasing field evidence that suggests that inelastic processes of the host rock play an important role in emplacement dynamics. We have studied a mafic dyke complex emplaced in the middle crust of an Ediacaran-aged magma-rich rifted margin in Northern Sweden. The host rocks in the field area are composed primarily of dolostone intercalated with silicic beds. The peak ambient temperature during dyke emplacement was approximately 700°C. Field observations show that the host rock beds are tightly folded (up to 30% shortening) close to the contacts of the surrounding dykes, and strain decreases rapidly with increasing distance from the dykes. The axial planes of the folds are sub-parallel to the dyke contacts themselves, suggesting that the folds formed as a consequence of dyke emplacement and inflation. Estimates of dykes cooling times suggest that the magma reached its solidus temperature within one year. Our results suggest that the strain rate accommodating dyke emplacement was very rapid (on the order of 10^{-7} s^{-1}) compared to typical tectonic strain rate estimates (ca 10^{-12} - $10^{-15}s^{-1}$). Our data show that inelastic deformation is an important aspect during dyke emplacement in the middle crust, and that fast strain rates are possible.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

2D analogue models of magma emplacement in the visco-elastic crust

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The Earth's crust exhibits very complex rheology depending upon several physio-chemical conditions like temperature, pressure and lithology. This complex rheology of the crustal rocks is challenging to model. Thus, most researchers model magma propagation through crustal rocks of end-member rheologies such as viscous, coulomb and elastic materials. However, they are not sufficient to capture the whole spectrum of rheological behaviours of the host rock. In this work, we performed a series of 2D magma injection experiments considering laponite gels as crustal rock analogues. According to our rheological measurements, laponite in deionised water solution exhibits a range of rheological behaviours from purely viscous to visco-elastic to purely elastic depending upon varying concentration (weight-percentage, wt%) in the water. We used laponite gels of 2 wt% to 3.5 wt% to test the effects of the gel's yield stress = [0.597 - 10.6] Pa as a lab-scale crustal rock analogue, and used dyed oil and water (viscosity= 65 and 1 mPa.s) as magma equivalents. Our experiments revealed a range of intrusion shapes, from thin liquid-filled cracks of simple to more massive fluid intrusions of complex shapes, indicating their varied mechanism of formation from brittle fracturing to ductile flow. To reveal gel deformation accommodating the emplacement of the intrusion, we implemented image analysis combining photoelastic properties of laponite gel and Digital Image Correlation. The resulting quantitative results allow us correlating the intrusion morphologies with the deformation mechanisms within the gel. Finally, we propose a model that connects the host rheology with the magma emplacement mechanism.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.8: Volcanic plumbing system models to inform volcanic unrest processes

Allocated presentation: Poster

Magnetotelluric Evidence for the Deep Causes of Different Eruptive Styles of Changbaishan Tianchi and Longgang Volcanoes in Northeast China

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Northeast China contains a large number of intraplate volcanic clusters, the Changbaishan volcanic system (CVS) is the largest in scale among them. Since these volcanoes are far from plate boundaries, the magmatic plumbing systems and the formation mechanisms of these intraplate volcanoes are still under debate. The broad CVS includes the Changbaishan Tianchi Volcano (CTV) (also known as the Paektu/Baekdu Volcano in North Korea), and Longgang Volcano (LGV). LGV and CTV share a common magmatic source at mantle depths. However, the two volcanoes have produced completely different types of eruptions. By performing 3D inversion of an MT dataset that completely covers the LGV and CTV, we have obtained high-resolution electrical resistivity images. The results reveal that the two volcanoes have distinct magmatic plumbing systems, and this is likely the reason for their different eruptive styles. Results from 3D modeling do not show a magma chamber in the shallow crust beneath LGV, interpreted as the rapid rise of the magma from the mantle is responsible for producing a series of densely distributed volcanic cones in the LGV field. In contrast, there is a magma chamber in the upper crust beneath the CTV, where the fractional crystallization and mixing of magma has occurred. This magma chamber has facilitated multiple centralized eruptions, and thereby has led to the formation of the large CTV volcanic cone. These results indicate that differences in their crustal structures may have controlled the different eruptive

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Talk [Invited]

4D crystallisation and dissolution kinetics in hydrous basaltic magmas: implications for dynamics of volcanic processes

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The crystallisation and dissolution of minerals plays a crucial role in the petrogenesis of igneous rocks, particularly under magmatic storage conditions, where the formation of crystal mush may occur, and within conduits during magma ascent. Disequilibrium textures in crystals, such as complex zoning, can result from rapid crystal growth, resorption, and diffusive re-equilibration. These textures reflect transitions between subliquidus and superheated conditions. Superheating, where the temperature exceeds the liquidus of crystal phases, can occur following the injection of hot, fresh magma into a storage region or via magma heating from decompression-driven crystallisation. Crystallization and mineral dissolution significantly influence the mobility and eruptibility of basaltic magmas, which, in turn, impacts volcanic risk assessments and mitigation strategies in active volcanic regions. However, the relationships between crystallinity, magma rheology, and eruptibility remain uncertain, largely due to the challenges associated with documenting these processes in real time. While crystallisation kinetics have been extensively studied through *ex situ* quench experiments, recent advances now allow for *in situ*, real-time investigation. Here, we present the results of three-dimensional, time-dependent (4D) high-temperature experiments conducted under water-saturated conditions using synchrotron X-ray microtomography. These innovative 4D experiments simulate crustal pressures and provide unique, quantitative insights into the crystallisation

and dissolution kinetics of pyroxene in basaltic magmas, examining their behaviour as a function of time, undercooling, and superheating.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Talk

Widespread and abundant interstitial silicic glasses in tholeiitic dykes of the Konkan Plain, western Deccan Traps: implications for silicic magma genesis in continental flood basalt provinces

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The petrogenesis of silicic magmas in continental flood basalt (CFB) provinces involves mechanisms ranging from fractional crystallisation to crustal anatexis. Silicic magmatism in the Deccan Traps of India, though minor overall, is concentrated along the western Indian rifted continental margin. We report widespread and abundant interstitial silicic glasses in tholeiitic basalt and basaltic andesite dykes exposed on the Konkan Plain, which were likely feeders to lavas forming part of the kilometers-thick Western Ghats volcanic sequence. Thermobarometric calculations for the dykes indicate co-crystallisation of clinopyroxene (1176–1115 ± 22 °C), olivine (1168–1135 ± 19 °C) and plagioclase (1181–1083 ± 14 °C), at pressures of 3.5–0.1 (± 1.5) kbar, suggesting crystallisation during magma ascent or storage in the uppermost crust. The interstitial glasses are dominantly rhyolitic (less commonly trachytic and rarely dacitic), and contain microlites of highly evolved plagioclase, pyroxene and olivine. The textures, whole-rock geochemical and mineral chemical compositions of the tholeiitic dykes and silicic glasses, and mass balance calculations, suggest the derivation of these silicic melts by 67-75% closed-system fractional crystallisation of their host tholeiites. However, the residual silicic melts, despite their considerable volumes, were unable to segregate from their mafic hosts. We relate this to H_2O loss on decompression during emplacement in the shallow crust, resulting in substantial undercooling, quenching, and trapping of the now-dry, extremely viscous silicic melts. This would explain well why the Western Ghats sequence notably lacks silicic extrusive or intrusive units, despite the widespread production and abundance of silicic melts at depth.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Talk

Origin of Silicic Magmatism at the Katla Volcanic Complex, South Iceland

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The Katla volcano is a bimodal caldera complex within Iceland's basalt-dominated Eastern Volcanic Zone. To unravel the petrogenesis of silica-rich rocks from Katla, we provide new $\delta^{18}O$ values for almost 60 basaltic, intermediate, and high-silica eruptive rocks, including a number of partially melted felsic xenoliths. The basaltic samples display a range in bulk-rock $\delta^{18}O$ values from +4.3 to +8.5‰ (n=17) and the sparse intermediate samples from +4.1 to +5.9‰ (n=3). In turn, silicic rock samples and feldspar separates range from +2.7 to +6.4‰ (n=38), whereas the felsic xenoliths yield the lowest values from -4.9 to -2.3‰ (n=4). The majority (95%) of the Katla silicic volcanics have $\delta^{18}O$ values below typical MORB (ie. ≤ 5.0‰), ruling out an origin via closed-system fractional crystallisation from the basaltic magmas. We utilised the new $\delta^{18}O$ values to model possible assimilation and fractional crystallisation (AFC) scenarios. The results indicate an early stage of FC/AFC at deep- to mid-crustal levels, followed by assimilation of low-$\delta^{18}O$ hydrothermally-altered sub-volcanic materials similar to the low-$\delta^{18}O$ felsic xenoliths at shallow crustal levels. Such a two-stage magma evolution is consistent with available geophysical and geobarometry studies at Katla, indicating mid- to deep-crustal as well as shallow-crustal magma domains. Importantly, mafic rocks show dominantly MORB-like $\delta^{18}O$ values, whereas low $\delta^{18}O$ values occur essentially in silicic rocks only. This implies that the low-$\delta^{18}O$ values at Katla are imposed by interaction with Icelandic crust, rather than reflecting low $\delta^{18}O$ in the underlying mantle sources.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Talk

Provenance of Deformed Olivine in Kīlauea's Summit and Lower East Rift Zone Eruptions.

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Deformed olivine in Kīlauea's summit and flank eruptions reveal re-entrainment from cumulate piles and complex magma pathways beneath the summit and East Rift Zone (ERZ). This study investigates cumulate and magma transport by analyzing olivine deformation in the 1960 Kapoho (68 crystals) and 2018 Ahuʻailāʻau (fissure 8; 174 crystals) eruptions, both on the lower ERZ, and six primarily juvenile Keanakākoʻi Tephra units (~1500–1800s CE; 423 crystals). Using electron backscatter diffraction (EBSD), olivines were classified as non-distorted, distorted, or deformed (mosaic textured or kink banded). Results reveal that 51% of Kapoho 1960 olivine show plastic deformation compared to only 12% of 2018 olivine. Larger grains (1 mm^2) are more commonly deformed. Deformed crystals are generally primitive (Fo_{85-90}), whereas undeformed olivines span a wide Fo range (Fo_{80-90}), with low-Fo compositions approaching equilibrium with carrier melts. This pattern is similar to many upper ERZ and Southwest Rift Zone (SWRZ) eruptions (Wieser et al., 2020), but the lack of large crystals makes 2018 distinct. Fewer deformed crystals among the 2018 olivine are consistent with published evidence for shallow crystallization. In contrast, the 1960 Kapoho lavas contain a higher proportion of deeply crystallized olivine, extending to 12 km depth (Moore et al., 2015), and have abundant large, deformed crystals. Keanakākoʻi tephra contains 22–36% deformed olivine. The olivine size, composition, and basic deformation patterns for most Keanakākoʻi units are similar to those of modern upper ERZ and SWRZ eruptions despite evidence for lower magma fluxes and more poorly integrated magma bodies during the Keanakākoʻi period.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Talk

How to emplace your rhyolite: Mechanisms for rhyolitic dike emplacement from field observations and microtextural analysis at Summer Coon volcano, Colorado, USA

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Rhyolitic eruptions exhibit complex behavior, involving hybrid explosive-effusive activity. These eruption dynamics are regulated by processes occurring in the deeper conduit. The nature of rhyolitic material at depth, whether a coherent, viscous magma, or a fragmented gas-pyroclast mixture, influences the interactions between magmatic material and host rock, as well as degassing paths for exsolved volatiles. Conduit morphology, and the accretion of material, may influence the progression of intrusion and eruption, but cannot be directly observed at modern systems. Data from ancient, exposed conduits can illuminate the dynamics and evolution of rhyolite intrusions at depth, and inform our interpretation of the processes occurring at modern volcanic centers. At Summer Coon, an eroded Oligocene stratovolcano in the San Juan volcanic field, Colorado, USA, three radial rhyolitic dikes are well-exposed within the edifice. We present data for one ~1.5-km long, segmented dike with paleo-depths during intrusion estimated to be ~1.1 km proximal to the edifice up to 0.7 km distally. Like the other two, it displays three distinctive zones from margin to interior: an obsidian rich, brecciated margin zone, a glassy flow-banded zone, and a platy interior zone. Brecciated margins are analyzed for clast size distribution and modal abundance (glass vs. lithics). This analysis is combined with SEM-BSE microtextural analysis of interior zones to determine the method of brecciation (shear or explosive fragmentation), and whether the interior represents re-sintered fragments or unfragmented magma. Comparison of these zones along the dike will allow us to characterize emplacement conditions over the course of intrusion.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Talk

The effect of crystal shape and growth history on fabric and permeability of magma mush

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Magmas in the crust are stored in crystal-rich mush zones with complex crystal inter- and over-growth textures and inter-crystal melt pathway geometries. For crystal-poor eruptions, large volumes of melt must migrate through the crystalline framework. To better understand the evolution of these melt pathways with time, we present an investigation of simulated magma mushes, comprised of three distinct cuboidal crystal morphologies with axial aspect ratios of 7:6:1, 20:6:1, and 15:5:3, respectively. Each of these morphologies undergoes associated changes in growth rate along different axes, with the faces perpendicular to the long axes growing at the fastest rates, and those perpendicular to the short axis growing most slowly. As growth of these crystals progresses, we calculate the permeability of melt through the system, constraining evolution of both crystalline intergrowth and melt-migration routes during mush formation. This research provides a detailed examination of the effects that different crystal shapes and associated growth patterns have upon magma crystallization and efficacy of melt permeability within magma bodies, with implications for timescales of eruption and recharge in volcanic systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Talk

The magma mushes and pre-eruptive magma bodies of the Bishop Tuff

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The Bishop Tuff (California, USA) is a zoned rhyolite supereruption deposit, which has been the focus of recent controversy about the architecture of the magmatic system. The deposit can be subdivided into three main portions: early-erupted units (EBT), which only appear in the East and South, are pyroxene-free, and are the first erupted units; eastern and southern late-erupted units (LBT-East), which are pyroxene-bearing and overlie EBT; and northern late-erupted units (LBT-North), which are not in direct contact with the other portions, but are pyroxene-bearing and inferred to be synchronous with LBT-East. We present 73 paired whole-rock and matrix-glass compositions for individual pumice clasts from all three portions, with the goal of assessing magmatic processes and the architecture of the magmatic system. We are particularly interested in pressures of magma extraction from crystal-rich mush and pressures of pre-eruptive storage derived using rhyolite-MELTS. EBT and LBT-East whole-rock compositions are relatively evolved and strikingly similar to each other; they contrast with LBT-North compositions, which are less evolved (e.g., lower SiO_2, higher Ba, Sr, LREE). LBT-East extraction pressures are the shallowest (~100-180 MPa), followed by EBT (~100-240 MPa), while LBT-North are deeper (~100-300 MPa). LBT-East and LBT-North cannot have tapped the same magma body; instead, EBT and LBT-East magmas are similar to each other. While magma storage pressures are similar for all magmas, the magma mushes from which they derived are distinct: EBT and LBT-East storage is contiguous with extraction, while LBT-North was extracted from a deeper and probably more extensive mush system.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Decoding melt-rock reactions in the deep crust of a magmatic arc: Insights from La Higuera ultramafic-mafic complex, Famatinian arc, Argentina

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Understanding and quantifying thermo-mechanical and thermo-chemical processes in the deep crust, especially during the early stages of magmatic evolution in trans-lithospheric magmatic systems, remains challenging. Ultramafic-mafic complexes in exposed deep crustal sections provide valuable opportunities to address these challenges. The Sierras Valle Fértil–La Huerta in the Famatinian Arc, northwestern Argentina, preserves an exceptional exposure of the deep levels of an Ordovician continental magmatic arc. This region features a continuous crustal section, from gabbronorite- and diorite-dominated lower crust in the west to tonalites and granodiorites in the mid-to-upper crust in the east, interlayered with hundreds of meter thick sequences of metapelites. Within the 10 km-thick mafic unit, at least 10 ultramafic-mafic complexes exhibit textural and chemical heterogeneities, offering insights into the emplacement mechanisms of mantle-derived magmas into the lower crust. We focus on La Higuera ultramafic-mafic complex, characterized by at least 3, up to 700 meters large, nearly concentric bodies with peridotite cores surrounded by olivine gabbronorite, amphibole gabbronorite and tonalites. Lithological transitions preserve extensive reaction zones that reveal evidence of melt-rock interactions, which follow two major geochemical and mineralogical trends: (1) a pervasive reactive melt trend associated with the formation and internal evolution of the ultramafic cores, and (2) a reaction trend between the ultramafic bodies and their more evolved mafic-to-intermediate hosts. These trends provide critical insights into magmatic processes governing the evolution and transfer of mantle-derived magmas into the lower and mid-crust, suggesting that reactive flow may be crucial in the early stages of magmatic evolution.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

What can quartz trace elements tell us? A machine learning approach for magmatic systems

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In recent years, the development of machine learning algorithms has provided scientists of different fields with a multitude of new possibilities to analyse and draw information from large, pre-existing datasets. In igneous petrology and volcanology, machine learning studies have found widespread use in reinterpreting trace element datasets, offering fresh insights into chemical evolution. In this study, we apply machine learning to investigate the trace element composition of quartz crystals from a diverse range of magmatic rocks (granitoids, lavas, ignimbrites, pegmatites, porphyry deposits, hydrothermal veins, and greisens) with varying chemical signatures (I-, A-, and S-types). Our results show that Al, Ti, Ge, and Li can be particularly useful for predicting quartz crystallisation environments. Through hierarchical clustering, an unsupervised machine learning algorithm, our model can classify quartz crystals into magmatic, magmatic-hydrothermal, and hydrothermal groups, which can be particularly valuable for uncovering chemical evolution in systems that have been overprinted by hydrothermal activity (e.g. porphyry-Cu systems). To validate our model, we tested it on the Tava Sandstone (Pikes Peak Batholith, CO, USA), a sedimentary unit with well-established quartz provenance, yielding successful results. These findings demonstrate that our model holds potential not only for deconvoluting overprinted/multi-stage complex chemical histories but also for supporting provenance studies in sedimentary geology.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Protracted magma evolution associated with plutonic activity in the transcrustal magmatic plumbing system of the Erta Ale Volcano (Afar, Ethiopia)

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The Erta Ale Range rift system, located in Afar, includes six distinct volcanoes with lava compositions that range from basalts to rhyolites. However, only the Erta Ale Volcano (EAV) is currently active, where, until now, only basaltic compositions had been reported. We now report prolonged differentiation at EAV, which is not manifest volcanically at the surface but is instead accessible through unique cognate gabbroic and microgabbroic blocks. These samples reveal evolved parts of EAV's plumbing system that were previously undiscovered. We analyzed the major and trace element compositions of bulk rocks, interstitial glasses, and melt inclusions, and examined the oxygen isotopic compositions of olivine crystals. We combined these findings with textural data and oxy-thermo-barometry to discuss magma differentiation, storage conditions, and magmatic interactions. Our research, compared with rhyolite-MELTS thermodynamic models, confirms that prolonged fractional crystallization, associated with reactive porous flow, are the primary mechanism of magma evolution at EAV. These processes lead to the evolved compositions observed, reaching up to 75 wt.% SiO_2. Oxygen isotopic analyses show substantial interactions with hydrothermally altered wall rocks. Finally, we also use the model outputs to quantify distinct phases of igneous differentiation in both shallow and deep crustal reservoirs, highlighting significant interactions and mixing between the different parts of the transcrustal plumbing system, particularly between the crystallizing plutons and dykes that accommodate the rift extension, and the ascending magma feeding the frequent eruptions. Pin et al., 2024. Journal of Petrology 65, egae118.
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Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Plumbing system processes unravelled through phenocryst texture, chemistry and in-situ Sr isotopes - The Pleiades Volcanic Field (Antarctica)

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The Pleiades Volcanic Field (PVF), in northern Victoria Land, Antarctica, is made up of a dozen monogenetic scoria cones and two domes, with ages ranging from ca. 800 ka to present. Despite the monogenetic aspect of the edifices, the volcanic products are compositionally diverse, defining a complete mildly Na-alkaline evolutionary trend. This makes the PVF a distinctive volcanic field, whose plumbing system has likely evolved under special conditions. To unravel the architecture of the PVF feeding system, we characterized the chemistry, texture and P-T conditions of crystallisation of the crystal cargo of a set of lavas, sampled in the framework of the Italy's National Antarctic Research Program - PNRA. Moreover, we performed in-situ Sr isotopes determinations on plagioclase crystals and groundmass with laser ablation multi-collector mass spectrometry (LA-MC-ICP-MS). Plagioclase phenocrysts display a wide range of textures (dusty mantles, coarse sieve textures, rounded cores), coupled with zonings in major (e.g. Ca-Na), trace elements (e.g. Ba) and Sr ratio (ranging in 0.7036-0.7043). Results on plagioclase suggest efficient recycling of crystals between magmas differing in evolution degree and radiogenic isotope signatures, as well as mixing with a low $^{87}Sr/^{86}Sr$ basaltic magma in the most mafic terms of the association. The complexity of pre-eruptive processes suggests a prolonged stall of the magma at crustal depths (1.2-0.1 GPa), with a main storage zone at around 0.3 GPa, probably due to an incapability of eruption. We suggest that a variable ice load could have played a role in modulating this long-lived and vertically extended subvolcanic system.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

A novel in-situ method to track the redox evolution of magmatic systems

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Magma redox, often expressed as oxygen fugacity (fO_2), plays a significant role in metal and sulfur transport in magmas. Oxidised conditions increase (1) copper transfer efficiency from magma to fluid in mineralising systems, and (2) magma viscosity and explosive potential in volcanic systems. The ferric-to-total-iron ratio ($Fe^{3+}/\Sigma Fe$) is used as a proxy to estimate the magmatic fO_2. However, quantifying $Fe^{3+}/\Sigma Fe$ often involves high analytical costs, limited accessibility, and sample damage. The novel Soft X-ray Emission Spectrometer (SXES) implemented on an electron probe microanalyser enables precise measurement of Fe-La, Fe-Lblines, and thus $Fe^{3+}/\Sigma Fe$ once the instrument is calibrated on matrix-matched materials measured by Mössbauer or X-ray absorption near edge structure (XANES) spectroscopy. Here, we present novel, *in-situ* $Fe^{3+}/\Sigma Fe$ determinations from silicate minerals (clinopyroxene and amphibole) and glasses (natural and experimental) previously characterised by Mössbauer spectroscopy and XANES [1-4]. Silicate phases from controlled-fO_2experiments of medium-K calc-alkaline basaltic and shoshonitic compositions are also presented to develop new oxybarometers. Caveats due to bonding effects such as non-linearity between the iron content and soft X-ray line properties will be discussed. This novel method allows the characterisation of the redox evolution of magmatic systems, adding a new dimension to our understanding of magmatic processes and the factors controlling the formation of ore deposits. [1] Cottrell & Kelley (2011), EPSL 305(3-4), 270-282. [2] Cottrell et al. (2009), Chem. Geol. 268(3-4), 167-179. [3] Kelley & Cottrell (2009), Science, 325(5940), 605-607. [4] Neave et al. (2024), CMP 179(5).

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Direct FE-SEM observation of crystallization in a rhyolitic silicate melt

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Nanocrystals in volcanic rock have recently attracted attention because they may influence eruption dynamics by increasing magma viscosity and serving as heterogeneous nucleation sites for bubbles. Hence, it is important to understand the crystal nucleation and initial growth processes in magmas. In the more commonly used heat and quench experiment, nucleation or nanocrystal crystallization may occur during the initial melting or quenching processes. Therefore, we attempted an in situ observation experiment that allowed continuous recording of the temporal evolution from heating to quenching. We succeeded in high-temperature in situ observation of crystallization in rhyolitic melt using field emission-scanning electron microscopy (FE-SEM). In our previous experiments under high-vacuum conditions, which was the first report of a non-classical growth pathway in magma, we observed metallic iron formation due to the low oxygen partial pressure and its growth by oriented attachment. In addition, in this study, attachment growth of iron oxide minerals, monomer-by-monomer growth, Ostwald ripening, and ultrananolite crystallization were observed under low-vacuum conditions adjusted by dry-air gas. Under sub-solidus conditions, we found that nanoscale liquid-phase immiscibility may promote the nucleation of ultrananolites. Understanding the occurrence of non-classical crystal growth pathways, depending on the composition and conditions of the magma, may contribute to better interpretations of the crystal size distribution and better understandings of the physical property evolution of ascending magmas.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Can volcanic activity and duration of repose times be modulated by the fertility of the mantle source? The case study of Methana volcano, Greece

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Magmatic systems often undergo periods of frequent eruptions, followed by quiescence. In some volcanic systems, these repose times may extend to tens of thousands of years, being highly challenging for hazard forecasting. As such, a volcano can be considered extinct before eruptions restart unexpectedly. We investigate this behaviour, along with the reasons for periods of extended volcanic quiescence and of intense volcanism. This is done by combining geochemical, isotopic and a zircon geochronological dataset of over 1,250 ages for 31 eruptions generated by Methana, an active arc volcano located 60 km south of Athens (Greece). With these data, we examine the connection between volcanic activity, magma reservoir evolution and changes in the mantle source over a timescale of 700,000 years. For this particular case study, prolonged repose times are coupled to variations in mantle source fertility. The longest volcanic pause recorded at Methana (>100,000 years) is not caused by a shortage of magma recharge, but marks an intense period of magma trapping in the crust, caused by the production of superhydrous melts (>6 wt% dissolved H_2O) from a fertile mantle. During ascent towards the upper crust, such volatile-rich magmas reach water saturation at around 3-4 kbar, leading to crystallization and to a decrease in ascent velocity by 2-3 orders of magnitude, with consequent trapping before they reach the surface. This mechanism can aid the growth of magma reservoirs and foster the transition from relatively small systems (like Methana or Mt. Saint Helens) to larger and more dangerous caldera-forming volcanoes.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

The production of large volumes of silicic magma in predominantly basaltic crust: Slaufrudalur pluton and the hidden volcanoes of Hornafjörður

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The generation of large volumes of silicic magma in basalt-dominated crust remains a topic of ongoing debate. Previous models (AFC vs. crustal melting) focus on the chemical processes only and largely ignore the mechanics of silicic magma production. To better understand the interplay between these processes, we study the Slaufrudalur pluton, the largest silicic pluton in Iceland (~8–10 km^3) and its surroundings. Despite previous studies investigating the pluton composition and emplacement, its existence within Iceland's basaltic crust has long been puzzling. Our new geological mapping, age data, and geochemical analyses from the Slaufrudalur region provide fresh insights into this problem. We identified several silicic central volcanoes hosting the pluton, and zircon ages from these silicic volcanics are the same, or younger than, zircons ages within the pluton. This indicates zircon recycling and suggests that the generation of this silicic magma was largely driven by the recycling of older silicic material from buried central volcanoes. Additionally, the spatial alignment of central volcanoes surrounding the pluton suggests its emplacement was strongly controlled by pre-existing structures. To further contextualize our findings, we also present geochemical data on plutons and volcanoes in the wider SE-Iceland area, highlighting the larger scale geodynamics at play. These findings allow us to present a temporal and spatial model for the production of large volumes of silicic magma in Iceland. Our results quantify the efficiency, speed, and structural controls of silicic magma generation and crustal recycling, shedding light on a key process in Icelandic magmatic systems.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Insights into the build-up to the early Permian Gargazzone super-eruption (Southern Alps) from high-precision zircon petrochronology

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The Athesian Volcanic District of the Southern Alps (Northern Italy) preserves an exceptional record of voluminous, evolved, early Permian magmatism developed in an extensional tectonic period between the Variscan Orogeny and the onset of Pangea's breakup. Volcanism began around 280 Ma, lasted at least 4 Myr[1], and produced eruptive materials spread over more than 4500 km^2. This magmatic activity is characterized by at least two caldera-forming super-eruptions. Efforts to reconstruct the magmatic history of this district have included detailed stratigraphic and mapping studies, as well as geochemical and geochronological analyses[2]. However, to better understand compositional, spatial, and temporal patterns in eruptive activity—and their correlation with recognized changes in the terrestrial ecosystem[3]—state-of-the-art, high-precision zircon U-Pb geochronology (i.e. CA-ID-TIMS) is required. In this contribution, we focus on the older of the two recognized caldera cycles, leading to the first collapse of pre-caldera volcanic edifices and the formation of the up-to-900-meter-thick Gargazzone Ignimbrite. Extensive sampling of the Gargazzone Ignimbrite across geographically and stratigraphically distributed outcrops was conducted to improve estimates of eruption volume. Zircon geochemistry and high-precision geochronology of these samples and volcanic units predating this event will be used to evaluate temporal and compositional changes of the Athesian magmatic system as it built up to the climactic event. [1] Boscaini, A. et al., *Contrib. Mineral Petrol.,* (2025) **180**, 10. [2] Marocchi, M. et al., *J Geol.*, (2008) **116**, 480. [3] Valle, F. et al., *Riv. Ital. Paleontolog. Stratigr.*, (2023) **129**.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

A glimpse into the magma dynamics beneath a large caldera; erupted magma mush fragments in the Rotoiti ignimbrite, New Zealand

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Magma mush fragments – crystal-rich, glass bearing clasts potentially genetically related to the erupted magmas – can provide important perspective on mush processes in active magmatic systems. Granitoid clasts from the Rotoiti Ignimbrite, Taupō Volcanic Zone (TVZ), include magma mush fragments that can provide insights on magmatic systems of one of the most active areas of rhyolitic volcanism in the world. This study focuses on a large (35 cm) layered clast found within a lag-breccia of the 64 ka Rotoiti Ignimbrite, one of the largest eruptions from the Ōkataina Volcanic Center (TVZ). This fragment is layered and can be divided into 5 zones. Backscattered Electron (BSE), Cathodoluminescence (CL), and Energy Dispersive Spectrometry (EDS) techniques highlight the textural and mineralogical differences between the zones. In this study, we focus on a fine-grained, biotite granite zone with microcrystalline patches and sparse granophyric texture. Quartz grains range from euhedral to subhedral, with complex zoning patterns that are visible in both BSE and CL. Some feldspar grains are zoned, others are not. The microcrystalline patches make up less than 10% of the sample and they are surrounded by subhedral grains (both quartz and feldspar). The interstitial texture and distribution of the microcrystalline patches indicate that this fragment is representative of a magma mush with <10% trapped melt. The average compositions of this microcrystalline material range from 72-77% SiO_2 and 4-6% K_2O and do not correspond with Rotoiti eruptive products; this mush fragment may illuminate older eruptive sequences of the TVZ.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Quartz and sanidine dissolution in silicic magmas

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Crystal textures record magmatic processes, but these records may be erased if the crystals dissolve in response to thermal or chemical disequilibrium. Many igneous rocks contain crystals that preserve evidence for partial dissolution. Crystal exteriors may be rounded or pocketed. Internal crystal zoning patterns may preserve cross-cutting relationships and unconformities. By analogy to their sedimentary counterparts, a crystal unconformity can be used to interpret the 'chronostratigraphy' of an otherwise unrecorded magmatic process. To explore the significance of the missing crystal record we performed a series of dissolution experiments using crystal-free rhyolite glass, to which we added sieved fractions of quartz and sanidine. Experiments were held at 775 to 875 °C and 100 to 250 MPa ($P_{total}=P_{H2O}$), producing conditions up to 100 °C above the liquidus, for up to 50 days. The resulting crystal textures were characterized using X-ray CT and petrography. Dissolution scales with both time and the degree of disequilibrium. At 100 °C disequilibrium both phases had fully dissolved in <300 hours, indicating average dissolution rates of ~1 μm h^{-1}. At 30 °C disequilibrium quartz and sanidine dissolved at ~0.1 μm h^{-1}. These dissolution rates are the same order of magnitude as crystal growth rates. Because natural crystals commonly preserve external and internal dissolution textures, the timescales of dissolution-inducing magmatic disturbances are often short enough to avoid full digestion. If dissolution textures are observed in mm-sized quartz and sanidine then episodes of thermal or chemical disequilibrium are unlikely to have lasted for more than a decade.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Does magma mingling trigger eruption by structurally disrupting the host crystal mush?

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Mafic magma mingling with crystal rich silicic mushes is often cited as a trigger for eruption. However, the mechanism is unclear – a key question is whether injection of hot, fresh magma can change the mush structure or melt fraction enough to permit remobilisation of large volumes of melt. In erupted magmas, there is no way to constrain changes in the original mush structure. In this contribution, we therefore examine the effect of mafic enclave mingling with silicic mush using a combined geochemical and textural approach in spatially constrained plutonic samples from the Lago Della Vacca tonalite, Adamello Batholith, Italy and the Searchlight pluton, Nevada, USA. We investigate the abundance and distribution of crystallising phases, the sizes, shapes and clustering behaviour of framework-forming mush minerals, and the packing fraction of the mush. We also use in situ Ti and La concentrations of plagioclase mantles and rims to track in-situ crystallisation of the mush. Plagioclase and amphibole cores are inherited from deeper in the crust, comprising ~45% initial crystallinity, suggesting that the magma emplaced into the crust as a slurry. Textural and geochemical evidence suggests minimal mush restructuring and remelting adjacent to enclaves except in extreme circumstances where pockets of mush are trapped between enclaves. This implies that mingling has limited structural effect on the mush. The Searchlight pluton provides a larger scale example of mafic magma mingling for comparison. This work presents a novel way to examine directly the effect of mingling on resident magmas prior to eruption.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Igneous distillation caught in the act: Insights from Compositional Stratification in the Middle Crust of the Famatinian Arc

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The Valle Fértil mountain range exposes a ~14 km section of the middle crust of the Famatinian magmatic arc, showcasing a compositional stratification with an intermediate unit (57–70% SiO_2) underlying a silicic unit (65–77% SiO_2). This arrangement provides the opportunity to investigate the evolution of magmatic reservoirs within the middle crust. We analyzed whole-rock major and trace elements, alongside with amphibole and plagioclase chemistry, to identify key petrological processes governing magmatic differentiation. Textural analyses show amphiboles and plagioclase forming an interconnected network with quartz, biotite and occasional K-feldspar occupying interstitial spaces. Minerals are arranged in a steep regional magmatic fabric across unit boundaries, with no significant disruptions, suggesting a homogeneous and continuous magmatic system. The variation in Al^{IV} vs Al^{VI} in amphiboles, indicative of pressure changes, reveals relative depth variations during magma emplacement. A fractional crystallization trend emerges in plutonic rocks, with decreasing MgO and Sr and increasing Rb concentrations with decreasing relative paleo-depths. Amphibole chemometry indicates melt compositions evolving from dacitic to rhyolitic, resembling volcanic rocks of the Famatinian arc. The lack of Fe-Mg equilibrium between amphiboles and their host rock, together with mineral orientation, supports some melt extraction from static mush zones, occurring dominantly via mechanical compaction and/or percolation flow. These findings suggest that middle-to-upper crustal plutonic rocks acted as a vertically-extensive mushy source reservoir for evolved melts that reach shallow depths (upper crust and surface). The chemical stratification of the magmatic column clearly reflects progressive differentiation during magma ascent.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Glass-bearing mush fragments reveal the plutonic-volcanic connection in the Taupō Volcanic Zone, New Zealand

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Fragments of mush erupted during large, caldera-forming eruptions give us a unique window into the plutonic systems that generate huge volumes of eruptible, rhyolitic magma. Here, we examine glass-bearing, crystal-rich mush fragments from the Taupō Volcanic Zone, New Zealand. Studied clasts were entrained in the 240 ka Ohakuri eruption, which evacuated 150 km^3 of high-silica rhyolite. Previous work revealed that eruptible Ohakuri magma was stored in at least two shallow magma bodies at <4 km depth, and was extracted from a heterogeneous, vertically extensive mush system at 4-13 km depth. We combine new insights from the mush fragments with this model of the Ohakuri magma system. Detailed textural analysis of the mush fragments was performed using optical and scanning electron microscopy. In situ compositions were collected with SEM-EDS and LA-ICPMS. Whole-rock compositions were collected by XRF. Intensive parameters were estimated with rhyolite-MELTS geobarometry. The mush fragments are hornblende gabbro, dominated by partially resorbed hornblende and euhedral plagioclase. Glass is interstitial, vesicular, and microlite-free. These textures suggest that the interstitial glass is trapped residual melt that quenched during eruption. Whole-rock compositions of the mush fragments are low SiO_2 (50 wt.%), overlapping in major elements with basalts from the TVZ. Glass is high-silica rhyolite (77.5 wt.% SiO_2), overlapping with the whole-rock composition of Ohakuri pumice. Geobarometry indicates that the mush fragments equilibrated shallow in the magma plumbing system (<4 km). Together, this suggests that rhyolites can be generated at very shallow depths from a single fractionation step of basalt to rhyolite.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Maximizing Microlites: Quantifying decompression-induced pyroxene crystallization

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Microlites—tiny crystals that form during rapid decompression and/or cooling in magma—provide valuable records of magma ascent. Plagioclase crystals are frequently used to reconstruct decompression histories, but pyroxene microlites remain comparatively under-examined. This limits our understanding of their crystallization dynamics and potential as complementary “speedometers.” This study focuses on pyroxene microlites, aiming to quantify their nucleation and growth rates in intermediate magmas during decompression, which are largely unknown. We investigate pyroxene microlites in natural eruptive products from various volcanic systems and through decompression experiments. Natural sample analyses, including 2D and 3D techniques, reveal microlite textures and growth patterns. Isothermal decompression experiments conducted using a cold-seal pressure vessel quantify pyroxene growth and nucleation rates as a function of decompression rate, supersaturation, and melt viscosity. Beyond interpreting ascent histories, understanding pyroxene microlite crystallization has significant implications for magma rheology and eruption dynamics. Syn-eruptive crystallization increases magma viscosity, directly influencing its mobility and eruptive style. By focusing on pyroxene microlites, this study provides a more nuanced understanding of magma ascent histories and the processes shaping volcanic eruptions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

The nature of crustal xenoliths brought to the surface with the 2021 eruption in Fagradalsfjall

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We studied 23 xenoliths from the 2021 eruption in Fagradalsfjall, Reykjanes Peninsula, Iceland. Based on modal composition we distinguished gabbro, olivine-gabbro, leuco-gabbro and anorthosite. Plagioclase is the most abundant mineral in every xenolith. In gabbros, plagioclase features bimodal size distribution, with smaller euhedral grains and larger subhedral grains. Clinopyroxenes are sub to anhedral and interstitial among plagioclase±olivine. Olivines, if present are generally smaller than the other two minerals, are mostly subhedral. Spinels are inclusions in olivines and plagioclases. Gabbros have ophitic and poikilitic texture. In anorthosites the plagioclases are anhedral to subhedral with porphyroclastic texture and sometimes with bent albite twinning. Plagioclases in all xenoliths are Anorthite (An)-rich with An66 to An95, in gabbros we get a narrower range from An75 to An90. Olivine has forsterite contents of 82-95. Mg# and Cr_2O_3 in clinopyroxene ranges from 82-88 and 0.2 to 1.46 wt%, respectively. Pressure and temperature of crystallization was calculated by clinopyroxene-melt thermobarometry and plagioclase-melt thermometry (Neave and Putirka, 2017, Putirka 2008). Median temperature from clinopyroxene-melt thermometry is 1208±4.1 °C (SEE of 27°C). The median pressure is 3.36±0.32 (SEE of 1.4 kbar) kbars, corresponding to crystallization depth of 9.4 ± 0.9 km (assuming the crustal density is 2.8 g/cm^3) for gabbros. Plagioclase-melt thermometry did not show differences between anorthosites and gabbros showing median temperature of 1232±8.1 °C (SEE of 36°C) for both rock types. These suggest that these xenoliths are sourced from the lower crust or perhaps the moho-transition zone as has been described for e.g.: the Oman ophiolite.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Differentiated magmas in a nascent island arc: the Nidar Ophiolite case in Ladakh, Indian Himalayas.

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The production of silicic magmas in intra-oceanic arcs is thought to play a crucial role in the evolution from basaltic oceanic crust to andesitic continental crust. The processes enabling the genesis of magmatic sequences with bulk andesitic compositions in these settings remain however elusive. The Nidar ophiolite (eastern Ladakh, Indian Himalayas) represents an early Cretaceous juvenile suprasubduction crustal sequence. Upper crustal plutonics, subvolcanic dykes and pillow lavas form two distinct differentiation series extending from basalts to respectively andesites and rhyolites. Basaltic to quartz-bearing rhyolitic dykes and lavas are geochemically and petrographically related to a suite of clinopyroxene-rich olivine gabbros, gabbros and gabbronorite. This series is characterized by subdued increase in incompatible trace elements. Later km-sized intrusions of hornblende-gabbro to quartz diorite form a second differentiation series characterized by marked increase in incompatible elements, except for LILE. Mafic magmas from both series have diagnostic geochemical features of arc melts but are more depleted than typical primitive arc basalts. Although variably enriched in LILE and HFSE, all differentiated magmas are significantly less enriched in these elements than the bulk continental crust. This work shows that substantial volumes of silicic magmas are produced through contrasted differentiation pathways in upper crustal magmatic systems during the earliest stages of intra-oceanic arc development. Despite their volcanic importance, these magmas appear to have limited influence on the geochemical maturation of the continental crust, as far as trace elements are concerned.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Quantifying magma deformation conditions from crystal-plasticity

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The evolution of multiphase magmas during shear remains a critical question in volcanology. The presence of solid, liquid, and gaseous phases partitions strain, and in suspensions with high interstitial melt viscosity, high crystal content, or low vesicularity, large stresses may accumulate in the crystalline phase, which may result in crystal plasticity and rupture. EBSD mapping of experimentally deformed, porous, crystal-rich dome lavas (at magmatic temperature) revealed that plagioclase (which dominated the crystal assemblage) underwent dislocation creep. The misorientation of the crystal lattices increased as a function of stress and strain, until rupture. Grain size reduction was seen synchronous to deformation, and fragments of broken microlites recorded the highest distortions; thus, crystals exhibit a plastic limit during dislocation creep. The systematic variation in plasticity with applied conditions demonstrates the key role of crystal plasticity in the deformation of crystal-rich lavas, and the possibility to interpret deformation from the imparted dislocations. To test this, we mapped crystal-plasticity in the lava spine erupted at Unzen in 1994−1995 and found that the degree of crystal lattice misorientation in plagioclase microlites increased systematically across the shear zone towards the marginal shear plane. This work demonstrates how crystal plasticity can map strain localisation textures formed during magma deformation, and although to date insufficient data exists to define the stress–strain history of magmas from the vestiges of crystal-plasticity, there remains hope for its use as a strain marker in the future, with further systematic quantification.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

The Role of Superheating in Controlling Crystallization Kinetics: Insights from the 2021 Tajogaite Eruption

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Thermal history of magma strongly affects crystallization behaviour, which, in turn, influences magma rheology and ultimately magma ascent dynamics. This study combines novel 4D (3D space+time) in-situ crystallisation experiments with ex-situ experiments to provide further insights into how different temperature profiles affect nucleation and crystallization kinetics in a tephritic magma composition from the 2021 Tajogaite eruption (La Palma, Spain). Using in-situ synchrotron X-ray microtomography, we directly observed and quantified the dynamic process of crystallization in real-time, capturing unprecedented detail on the interplay between superheating (i.e. temperatures exceeding the liquidus temperature of its most refractory mineral phase) and nucleation. Experiments were conducted under two thermodynamic conditions: (1) in-situ synchrotron X-ray microtomography at 20 MPa without superheating and (2) ex-situ crystallization at 275 MPa after superheating (88 °C above $T_{liquidus}$). The timing of clinopyroxene nucleation differed markedly between the two experimental conditions, with nucleation initiating within 20 minutes in the in-situ experiments but delayed by 8 hours in the ex-situ setup. This difference arises from the resorption of pre-existing nuclei during prolonged exposure to superliquidus temperatures (1200 °C) in the ex-situ experiments. The experimental results suggest two alternative crystallization behaviours: (i) without superheating rapid

crystallization is promoted due to minimal nucleation delay (in terms of minutes), and (ii) with superheating crystal nucleation is delayed for several hours. These distinct crystallization behaviours critically impact magma rheology, influencing processes like degassing, fragmentation, and eruption dynamics. This study underscores the pivotal role of superheating in crystallization kinetics and its implications for volcanic hazard assessment.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

A petrochronological approach to alkaline ring complexes: new U/Pb ages for the Lake George Ring Complex, Pikes Peak batholith, Colorado

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The Pikes Peak batholith (PPB) hosts multiple alkaline intrusions categorized as a 'sodic' or a 'potassic' series. They were interpreted as late-stage intrusions based on field relationships (Smith et al., 1999). This study investigates the formation and geological history of the Lake George Ring Complex (LGRC) and its relation to the PPB through petrological and petrochronological analyses. The LGRC is at the PPB's western margin and displays concentrically zoned lithologies of both types. As ring structures are often linked to ancient caldera systems, the LGRC and other alkaline intrusions may represent the remnants of volcanic activity associated with the emplacement of the PPB. The LGRC outer rim is a monzogranite (74wt.% SiO_2, 9.4wt.% Na_2O+K_2O) crosscut and mingled by high-Na mafic dikes (58wt.% SiO_2, 10.5wt.% Na_2O+K_2O). Next is a quartz syenite (66wt.% SiO_2, 10.5wt.% Na_2O+K_2O) and finally a 'sodic' core of syenomonzonite (64wt.% SiO_2, 11.2wt.% Na_2O+K_2O), with a few olivine ($Fo_{36\text{-}39}$) gabbro bodies in the center (46wt.% SiO_2). New zircon U/Pb ages clarify the relative ages of the concentric lithologies, shedding light on their petrogenesis. The current consensus favors a late emplacement of smaller intrusions relative to the parent pluton, though ages by Guitreau et al. (2016) challenge this interpretation for the LGRC. We hypothesize that some LGRC lithologies are cumulates and seek evidence of crystal-melt separation. The release of fluids by the crystallizing magmas may have altered the lithologies of the LGRC. Guitreau, M. et al. (2016). *Precambrian Research*,*280*, 179–194. Smith, D. R. et al. (1999). *Precambrian Research*,*98*, 271–305.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Paleomagnetic and Geochemical studies of Paleoproterozoic mafic dykes of WDC: constraints on magma plumbing systems.

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The Dharwar craton in southern India represents one of the oldest and well-preserved Archean crustal blocks and is characterized by a complex tectonic history, with the presence of late-Archean greenstone belts that are intruded by granitic plutons. One of the key features of the Dharwar craton is the presence of widespread mafic dyke swarms giving us a glimpse of the magmatic and tectonic evolution of the region. Old and discontinuous dyke swarms cut through the older western Dharwar craton and hence is lesser studied than the Eastern Dharwar craton. The WDC, with its complex history of magmatic intrusions and dyke swarms, offers a unique opportunity to investigate these connections. Here we present new paleomagnetic and geochemical data along with in-depth study of magmatic origin of these mafic dykes and account of the LIP's that occurred concurrently, the role of precious metal emplacement through these conduits and large fracture systems. The orientation and distribution of dykes found in the WDC reveal the prevailing stress field during magma emplacement. Dykes often propagate perpendicular to the minimum compressive stress, providing a record of past tectonic stress regimes, Our current document highlights the presence of older, discontinuous dyke swarms in the WDC, suggesting a complex tectonic history and the magma chamber geometry through the shape and depth of magma chambers. These chambers can be influenced by tectonic forces. e.g.-extensional settings may favor the formation of shallow, elongated magma chambers, while compressional settings may lead to deeper, more vertically oriented chambers. WDC- Western Dharwar Craton

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Crystallographic relationships in amphibole reaction rims: Insights into breakdown mechanisms and dynamic magmatic processes

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Amphibole serves as a critical archive of magmatic conditions due to its high sensitivity to perturbations in temperature, pressure and volatile content. Understanding the processes driving amphibole breakdown is essential for reconstructing magma evolution and identifying the eruption triggers. Upon destabilisation, amphibole forms reaction rims composed of clinopyroxene, orthopyroxene, plagioclase, and Fe-Ti oxides, which serve as chemical and textural fingerprints of breakdown mechanisms. However, interpreting these rims can be complicated by the interplay of intensive variables (P–T–X) and dynamic factors, such as shear and melt viscosity, that influence rim textures. We use electron backscatter diffraction (EBSD) to investigate the crystallographic orientation of amphibole and its reaction rim microlites from natural volcanic systems (Soufrière Hills, Unzen, El Misti, and Bezymianny) and experimental products. Clinopyroxene often exhibits a crystallographic alignment with the host amphibole, indicating a degree of structural inheritance and topotactic relationship, while for other phases, such as orthopyroxene and plagioclase, such a relationship is more ambiguous. Experimental rims produced by heating and CO_2 flushing exhibit strong topotactic relationships (0º misorientations) consistent with rapid epitaxial growth. Natural rims exhibit a wider variety of misorientation distributions, ranging from strongly topotactic (0º) to larger misorientation angles (60º–80º), and sometimes bimodal distributions within single rims, indicating additional dynamic influences brought about during decompression, such as shear and localised melt heterogeneities. By linking microstructural features to destabilisation processes and magma dynamics, this study provides new insights into amphibole breakdown, magma ascent, and eruption, offering a new framework for interpreting pre- and syn-eruptive magmatic conditions.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Seeing through volcanic rocks, every mineral all at once

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Volcanic rocks are chemically and texturally complex products of subsurface magma systems that we cannot directly observe. Crystals within, however, provide us windows into how these systems work, but our interpretations of their records rely on how we access their interior features. Since thin section petrography was developed in the mid-19th century, it has remained a standard practice used by geologists to access and characterize rock interiors. Today, dissecting rocks is inherent to the majority of established techniques used to analyze rock and mineral chemistry, texture, and age. Although it leads to information loss, what is gained is valuable and contributes to our foundational understanding of volcanism. There may be more to learn, however, if we could gain access to crystals initially without dissection and in three-dimensions. Crystal architectures are multi-dimensional, over time recording magmatic conditions and dynamics in their chemical structures, orientations and twinning, sizes, shapes, imperfections and inclusions. In recent decades, X-ray microtomography has paved a way to visualize and measure these characteristics in 3D. Here we develop a workflow combining state-of-the-art X-ray modalities and correlative tools that are poised to change the way we approach petrological research. Using lab-based, absorption and diffraction contrast tomography, we non-destructively map in 3D the physical attributes and crystallographic orientations of multiple mineral phases in a rhyolitic pumice. Visualizing and quantifying 3D spatial relationships between every mineral and every crystal all at once brings new opportunities to contextualize and target the most valuable features in down-stream, traditional 2D analyses.

Theme: 1. Production of magma and assembly of volcanic plumbing systems

Session 1.9: Perspectives on magma storage and transport in the crust – lessons from mineral compositions and crystal textures in volcanic and plutonic rocks

Allocated presentation: Poster

Segmentation of zoned plagioclase crystals from Plinian eruptions of Mont Pelée: Implications for the characterisation of source magmas and understanding of eruption dynamics

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The eruptive history of Mont Pelée is interspersed by multiple Plinian events that have been associated with widespread ash and pumice fallout deposits across the north of Martinique. These events represent some of the most explosive eruptions produced by Mont Pelée. Here, we present chemically calibrated maps of plagioclase crystals from six different Plinian events. Major element maps are calibrated using Electron Microprobe analyses of either complete thin sections or epoxy-embedded single crystals. Segmentation of plagioclase crystals identifies distinct zoning groups (spatially constrained regions of similar An#) that are found in multiple crystals and different eruptions. These zones range in composition with median An# between 53 to 88. By quantifying the complexity of the zoning, we can characterise a so-called “genetic profile” for different events. No event contains all zoning groups and, in general, profiles can be distinguished based on whether they contain high An# groups or not. Additionally, if the lowest An# group is present in a sample, it is the most dominant of all zoning groups. By characterising these genetic profiles, we can begin to investigate the links between the intensity and evolution of each eruption, and the regions from where magma was periodically stored and/or erupted. Additionally, the technique allows us to target crystals for more focused trace-element mapping and verify the field-derived correlation of volcanic units.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

Explosions in the Sky: Seismo-acoustic and crowdsourced observations of the 2022 eruption of Hunga volcano from across Aotearoa New Zealand

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On 15 January 2022, Hunga volcano (Kingdom of Tonga) underwent one of the largest volcanic eruptions in recent history, generating long-range audible sounds that were reported across the world, including the length of Aotearoa New Zealand. This presented a rare opportunity to document and analyse the long-range propagation of audible volcanic acoustics from both geophysical and social perspectives. Public observations were obtained from a crowdsourced survey to understand the spatial and temporal distribution of eruption sound observed across the country. The results of the survey complemented a dense seismo-acoustic record, including data from microphones, barometers, seismometers, and strong-motion accelerometers. Over 1700 members of the public reported hearing multiple "booming" noises over a 2-hr period on 15 January 2022, perceiving a "light" or "moderate" loudness (proportional to 60 – 80 dB). Manual analysis of seismo-acoustic data in the North Island found >140 events across two distinct wavepackets within the same 2-hr period, of which 7 had amplitudes >60 dB. Detailed analysis of the seismo-acoustic data clearly recorded two southward-propagating acoustic wavepackets. The first coincided with a Lamb wave generated by the eruption but the second propagated at a slower apparent velocity (~270 m/s) and was likely associated with an extremely rare Pekeris wave. This presentation highlights how crowdsourced data can engage the wider public in volcanology, how joint analysis with geophysical data is shedding new light on a historic eruption, and how such multi-disciplinary studies may be used to understand future volcanic activity.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

Analysis and modeling of Deep Long Period volcanic earthquakes to illuminate the roots of magmatic-plumbing systems beneath the active volcanoes

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Long-period earthquakes and tremors form one of two main classes of volcano-seismic activity. Deep long-period (DLP) earthquakes are particularly interesting because usually they are attributed to the processes occurring in the deep roots of the magma plumbing systems in the vicinity the crust-mantle boundary. The DLPs are often considered as manifestations of deep magmatic reactivation and possible early precursors to eruptions. The physical mechanism of generation of the DLP earthquakes remains, however, not fully understood. To advance toward more quantitative interpretation of the DLP seismicity in terms of underlying magmatic processes, a systematic analysis of their observations needs to be combined with physical modeling of their sources. In this presentation, we compare observations of DLP seismicity in several volcanic regions with different data analysis approaches. We then discuss how these observation can be interpreted in the framework of the models implying the supply of fresh magma from the mantle to the crust. One considered DLP generating mechanism consists of the rapid growth of gas bubbles in response to the slow decompression of $H2O–CO2$ over-saturated basaltic magma. The nucleation and rapid growth of gas bubbles lead to rapid pressure change in the magma and elastic rebound of the host rocks, radiating seismic waves recorded as DLP earthquakes. Another possible mechanism is related to time-varying viscous traction forces because of the intermittent magma flow.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

Template matching for identification of hydro-acoustic signals to monitor underwater eruptions

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Volcanic eruptions predominantly occur underwater, but the study of these eruptions remains a significant challenge due to limited site accessibility and the lack of continuous high-resolution data. Consequently, the temporal processes driving the construction of submarine volcanic edifices remain poorly understood. From 2018 to early 2021, one of the largest recorded submarine eruptions occurred 50 km east of Mayotte, in the Mozambique Channel, leading to the birth of the Fani Maoré volcano. The Fani Maoré eruption presents a rare opportunity to study submarine volcanic dynamics. Form early 2019 to the end of the eruption, ocean bottom seismometers (OBS) deployed offshore Mayotte have recorded hydro-acoustic signals generated by the eruptive activity. These signals provide unprecedented temporal precision for tracking volcanic activity and lava flow emplacement. In this work, we employ template matching to detect impulsive hydro-acoustic signals from the hydrophone component of the OBS dataset. Templates are constructed by clustering manually picked events. We then associate the detected signals with their sources to reconstruct the spatio-temporal variability of eruptive activity. This approach enables us to highlight key phases of the eruption, offering new insights into submarine volcanic processes and paving the way for continuous, high-resolution monitoring of underwater eruptions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

Detecting and Classifying Volcano Seismicity using a Generalized Deep Learning Model

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Volcano seismicity is often detected and classified based on its spectral properties. However, the wide variety of volcano seismic signals and increasing amounts of data make accurate, consistent, and efficient detection and classification challenging. Progress has been made applying machine learning to volcano seismicity, but efforts have typically been focused on a single volcano with limited training data. We build on the method of Tan et al. [2024] to generalize a spectrogram-based convolutional neural network termed the VOlcano Infrasound and Seismic Spectrogram Neural Network (VOISS-Net) to detect and classify volcano seismicity at any volcano. We use a diverse training dataset of over 270,000 spectrograms from nine volcanoes worldwide that present a range of volcano seismic signals, source-receiver distances, and eruption styles. We apply VOISS-Net to continuous data from several volcanoes and eruptions within and outside the training set including Mt. Etna, Italy; Shishaldin and Semisopochnoi, Alaska; and Kilauea, Hawaii. VOISS-Net successfully detects and classifies multiple types of tremor, explosions, earthquakes, long-period events, and noise, but occasionally confuses earthquakes and explosions and misclassifies seismicity not included in the training dataset. We envision the generalized VOISS-Net model to be applicable in both research and operational volcano monitoring settings, as demonstrated by its recent application at the Alaska Volcano Observatory. Reference: Tan, D., Fee, D., Witsil, A., Girona, T., Haney, M., Wech, A., Waythomas, C., & Lopez, T. (2024). Detection and Characterization of Seismic and

Acoustic Signals at Pavlof Volcano, Alaska, Using Deep Learning. Journal of Geophysical Research: Solid Earth, 129(6), e2024JB029194. https://doi.org/10.1029/2024JB029194

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

How can we constrain connections between volcanic seismic signals and eruptive behaviour at Mt Etna?

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Volcanic seismicity is a powerful indicator of activity at volcanoes worldwide, providing information on volcanic structures and subsurface processes such as magmatic fluid transport. Volcanic systems produce a range of eruptive styles and durations; determining whether future eruptions will be explosive or effusive is key for reducing the hazards faced by local communities. Mt. Etna is the largest volcano in Europe and is continuously monitored by a substantial seismic network providing an ideal location to quantitatively constrain links between eruptive styles and seismicity. During periods of intense volcanic activity, many seismic events will go undetected. Repeating earthquakes are events that have identical waveforms, implying they are from the same source origin and mechanism. A matched filter search identifies repeats of template events, including those which are hidden behind the noise, and can increase a seismic catalogue by a factor of 10. Separating seismicity into families of similar waveform properties, provides a way to monitor how the seismic signal evolves through time, building a framework that can be linked to subsurface processes and eruptive styles. Here we focus on a flank eruption in December 2018 which saw a large increase in seismicity during the first few days of the eruption. We use events detected by the INGV seismic catalogue in December 2018 as templates for a matched filter search. We investigate spatial and temporal trends in families grouped by waveform similarity to understand subsurface processes and structures, providing a quantitative comparison with the vast and complex eruptive history of Mt. Etna.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

Spectral Line Variability in Volcanic Tremor as a Proxy for Subsurface Changes: Observations from Etna Volcano

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Episodes of volcanic tremor provide valuable insights into the dynamics of subsurface processes at active volcanoes. Previous studies have suggested that evolution in tremor properties, such as frequency and amplitude, may relate to changes in the stress conditions of the plumbing system. However, a strong causative link has remained elusive. At Etna volcano, we observe changes in the frequency of broadband tremor during a prolonged seven-month episode of unrest and eruptive activity in 2020. A comparison with seismic velocity changes computed at multiple stations using passive seismic interferometry reveals an intriguing consistency between the evolution of tremor spectra and seismic velocities. Furthermore, variability in seismic velocity changes across different stations, with closely matching spectra evolution, suggests that these phenomena are not simply related to a change in seismic source frequency. Instead, we propose that the spectra are evolving in response to a phase velocity change within the medium, as evidenced by our measurements of seismic velocity. These findings highlight the sensitivity of tremor spectra to changes in subsurface conditions, thus providing a new perspective on the relationship between spectral evolution and medium properties. Our results confirm that monitoring spectral changes offers a promising approach for tracking subsurface conditions within volcanic plumbing systems.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

Tracking Volcanic State Transitions Through Seismic Velocity Changes: Insights from Askja, Aso, and Gareloi Volcanoes

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Identifying the transition from volcanic quiescence to unrest remains a critical challenge in volcano monitoring. This study advances our understanding of volcanic state transitions by analyzing continuous seismic records from three volcanic systems: Askja (Iceland), Aso (Japan), and Gareloi (Alaska, USA). We employ a multi-parametric approach combining seismic velocity changes (dv/v), kernel sensitivity analysis, and seismic attenuation measurements to track subsurface evolution over time. We integrate ambient noise cross-correlation using MSNoise to compute attenuation and detect seismic velocity changes, with source locations constrained by surface wave kernel sensitivity across different frequencies and velocity models. Results show distinct patterns of unrest across sites. At Askja, we detected a pronounced decrease in dv/v at approximately 2 km depth in August 2021, concomitant with increased attenuation, shallow microseismicity, and the initiation of surface uplift (80 cm over three years). At Aso, the 2016 Kumamoto earthquake induced an immediate 0.5% decrease in dv/v, followed by a healing process and increased attenuation, interrupted six months later by an eruption marked by 0.3% dv/v decrease. At Gareloi, 2021 seismic unrest is characterized by tremor and persistent long-period events over three months, corresponding with a 1% dv/v decrease at roughly 3 km depth. These diverse case studies demonstrate how continuous monitoring of seismic velocity changes and attenuation reveals both gradual and sudden transitions in volcanic systems. In addition, our findings establish baseline behaviors for these volcanoes and highlight

characteristic seismic signatures associated with unrest, thereby advancing our capability to detect and interpret potential precursors to volcanic eruptions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

From Geysers to Volcanoes: Connecting Fountain Dynamics with Acoustic and Electrical Signatures

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Geysers serve as natural laboratories for studying dynamics analogous to those observed during volcanic eruptions, offering a safe and accessible environment for investigation. During multiple field campaigns, we recorded acoustic and electric signals generated by the eruptions of Strokkur Geyser, Iceland, complemented by high-resolution video observations. Acoustic signals have historically been used to infer eruption dynamics, and in this study, we extend this approach to incorporate simultaneous electrical signal measurements. A typical eruptive sequence at Strokkur begins with a water bulge driven by bubble clusters that displace the overlying water, producing characteristic low frequency acoustic (infrasound) signals. These M-shaped signals are generated by the displaced volume as the bulge grows as well as the disintegration after rupture. With the onset of the rupture, higher-frequency acoustic signals (>10 Hz) and electrical signals emerge, peaking during the brief fountaining phase, which lasts approximately 1.5 seconds. Notably, the electric signals exhibit a distinctive, self-similar N-shaped waveform across events. Here we use high-speed video analysis to quantify the velocity, acceleration, and height of the leading edge of the water fountain, providing a detailed connection between fountain dynamics and the observed acoustic and electrical signals. Our analysis has already established that the bulge growth at Strokkur Geyser and its associated acoustic signals resemble those observed during Strombolian eruptions, such as at Erebus Volcano in Antarctica. This promising result sets the stage for further exploration, as we aim to identify similar connections when analyzing the detailed dynamics of the fountain itself.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

A Novel Framework for Magma Supply Rate and Depth Controls on Volcanic Earthquake Magnitudes

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Many active, high threat volcanoes are monitored seismically; some volcanoes display escalating unrest that leads to timely forecasts, while others erupt with little seismic expression. Such has been the state of affairs for decades, and progress will come from integrating geophysical data with petrological data to elucidate the state, location and movement of magma in the sub-volcanic system. Here we focus on the depth evolution of seismic unrest and the relationships to magma storage, crustal rheology and recharge rate. Some volcanic systems display only shallow seismicity in the run-up to eruption, with earthquakes then deepening during the on-set and continuation of eruption ("Top-Down" behavior,). Other eruptions are presaged by deep seismicity that is typically interpreted as magma and/or vapor ascent ("Bottom-Up" behavior). We present a novel framework, based on experimental rock mechanics studies, for the influence of magma supply rate (proxied by strain rate) and temperature and confining pressure (proxies for increasing depth), which illustrates how higher magma flux leads to more abundant seismicity at a given depth/temperature. Critically, this framework demonstrates a relationship between depth and expected earthquake magnitude at a given strain rate (i.e., deeper earthquakes should have lower magnitudes at a given strain rate). Thus we predict that deep earthquakes at volcanoes with high magma flux should have larger magnitudes relative to those at low-flux systems, and test this prediction through assessment of key case studies for which independent constraints on magma flux exist.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

Understanding Vulcanian Eruptions Through Seismograms Obtained From Unsteady Conduit Flow Models

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Vulcanian eruptions are violent and explosive events caused by the destruction of a solid plug in the uppermost volcanic conduit. We introduce an inversion and modeling workflow applied to the powerful 14 July 2013 Tungurahua, Ecuador, vulcanian eruption to understand the initiation and evolution of the eruption. This is done by integrating conduit flow modeling with seismic data. We use QVolc (Lam, 2024), which solves the unsteady mass, momentum, and energy balance equations for a multi-phase magma with exsolution and fragmentation. Initial conditions are obtained in two steps. First, we invert seismograms for vertical seismic force, using 3D Green's functions with topography and heterogeneous properties, where we interpret the initial downward force as the loss of flow resistance from plug failure. Second, to obtain pre-eruptive conditions for the unsteady case, we solve the magmastatic problem with additional flow resistance from the plug and constrained by the inverted force. The added resistance provides overpressure that drives the eruption. The eruption simulation is initiated by eliminating the plug flow resistance, corresponding to plug failure. Next, we convert changes in shear stress and pressure on the conduit walls into seismic force and moment sources (Coppess et al., 2022), which are convolved with Green's functions to generate seismograms. The predicted displacements are compared with observations. We adjust the plug's depth extent, flow resistance, and failure timescale to match the seismic data. We are extending our modeling above the vent to integrate infrasound data. This workflow provides insight into the physical processes driving Vulcanian eruptions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

Waveform inversion of acoustic-gravity waves during the 2023 eruption of Shishaldin volcano, Alaska

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We report on low frequency signals, extending to periods as long as 22 minutes, observed on local infrasound sensors during the 2023 eruption of Shishaldin volcano in Alaska. Such signals have been identified globally following other large eruptions and we focus on high-quality recordings from one of the largest paroxysms during the months-long Shishaldin eruption (Event 11, starting ~13:35 UTC September 25, 2023). We observe peaks in the amplitude spectrum at 0.75 and 1.5 mHz (22 and 11 minutes period) after applying broadband instrument correction to data from an infrasound station ~6 km north of the vent. Analysis of radiosonde data from nearby Cold Bay, Alaska, indicates these signals are at or below the atmospheric buoyancy frequency and therefore we model the signals using acoustic-gravity theory. Assuming a mass source with a source-time-function given by a Gaussian located above the vent, we perform a grid search inversion based on waveform fitting for 2 parameters: the source elevation and time duration. We obtain good waveform fits, especially for the initial 20 minutes of the signal, for a source located 1.7 km above the vent. We estimate a peak mass eruption rate of 10^8 kg/s and, by integrating the source-time function, we find a total erupted mass of 4.3x10^8 kg. This erupted mass agrees to within a factor of 2 with an independent estimate based on satellite observations of sulfur-dioxide emissions and suggests acoustic-gravity waves can be used to estimate critical eruption source parameters in near real-time.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

A New Perspective on Earthquake Triggering of Volcanic Unrest

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The scientific literature contains many suggested cases of volcanic eruptions triggered by large regional earthquakes. These studies generally fall into two categories: 1) case studies examining the effect of a single earthquake on a specific volcano or 2) global "earthquake-centric" studies that analyze changes in eruption rates at volcanoes in some region around a large earthquake. These studies are generally limited to earthquakes of >=M6 and to eruptions of >=VEI 2. They also neglect crustal relaxation and the cumulative effect of multiple earthquakes. Here, we present a new "volcano-centric" methodology to address this critical issue. We calculate both the static and dynamic strain changes that a volcano "feels" from all earthquakes, regardless of magnitude. Thus, we generate time series of earthquake-induced strain changes at specific volcanoes that can be compared to measurable volcanic unrest. We apply our method to three volcanoes with differing tectonic settings and eruptive styles: Mt. Redoubt (USA), Turrialba volcano (Costa Rica), and the Taupo volcanic zone (New Zealand). We find no clear relationship between earthquake-induced strain changes and eruptions at Redoubt and Turrialba. At Taupo we find that the cumulative effect of earthquakes helps explain a potential earthquake-induced intrusion. Finally, we also find that nearby earthquakes <M6 may impart a larger strain change on the volcanoes than more distant larger earthquakes, and that the cumulative strain on volcanoes from more frequent smaller earthquakes can exceed the strain from individual large earthquakes. Thus, prior studies on this topic may be using an incomplete dataset.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Talk

How does a dike open? Insight from seismic source modelling of the earthquakes preceding the 2021 Tajogaite eruption (La Palma, Canary Islands).

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The 19th Sept. 2021 eruption of the Cumbre Vieja volcano (La Palma, Canary Islands) was preceded by a week of intense seismicity. Hypocenters migrated westward and upward, following the path of bent and twisted dike. During the precursory phase, earthquakes reached a magnitude up to 3.4; however, in the morning of Sunday, 19th Sept. 2021, just a few hours before the eruption onset, a magnitude 4.1 earthquake shook the island and marked the opening of eruptive vents. In this work, we analyse the mechanism of these precursory earthquakes using a finite fault model with an elliptical geometry. We model the full wavefield using a discrete wavenumber approach (Axitra software), parametrising individual seismic sources using a grid of point sources. We apply this methodology to a selected subset of earthquakes with magnitudes higher than 3.0 and show how the fault geometry and mechanics relate to the local crustal structure and the dike propagation dynamics. In particular, we focus our analysis on the vent opening phase, showing the relationship between local volcano-tectonic dynamics and the earthquake mechanism.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Deccan Trap Volcanism: A Local Driver of Medium-Scale Seismic Activity in Peninsular India

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Peninsular India (PI), spanning 8° to 25°N and 68° to 88°E, is also known as the Precambrian Shield and generally experiences low seismic activity compared to the more tectonically active Himalayan collision zone. However, the Deccan Traps, a vast and geologically significant volcanic formation covering about one-third of PI, represent the region's youngest and most prominent geological feature. While most of PI has an older, thicker crust and lithosphere, the Deccan volcanic activity persisted for roughly 4 million years, creating a Flood Basalt Zone (FBZ) where subsidence of adjacent crustal rocks into the upper mantle has occurred. Basalt solidus within these FBZs lies at depths between 22 to 36 km, and these zones are identified by distinct gravity anomalies. Seismic data from 1900 to 1993 indicate that the Deccan Traps are more seismically active than the rest of the shield, releasing about 4.5 times the energy. A model is proposed to explain how medium-sized earthquakes occur in this trap-covered region: undulations in the Moho boundary create faults and fractures, allowing fluid to enter the upper crust. This fluid accumulates in cracks, generating stress and potentially triggering seismic events. Acting as a lubricant, the fluid also facilitates fault slippage, making these areas susceptible to medium-sized earthquakes that could present future seismic hazards.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Seismicity and Focal Mechanisms of Ceboruco Volcano (Mexico) from a Dense Seismic Network: Insights into Recent Activity and Potential Future Eruptions

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Ceboruco Volcano is a stratovolcano located in the western region of the Trans-Mexican Volcanic Belt; at this volcano, effusive-explosive episodes have accompanied eight eruptions during the last 1000 years, providing an average of one eruption every 125 years, the last eruptive period was 1870–1875, it is considered one of the most hazardous volcanoes in Mexico. We have conducted a detailed study of the seismicity in the surroundings of Ceboruco's volcanic edifice to assess the current state of this volcano. As part of the P-24 project of the CeMIEGeo consortium. A dense temporary seismic network with 25 seismic stations in an area of 16 km × 16 km was deployed between November 2016 and July 2017; this effort has allowed the detection of 81 earthquakes concentrated beneath the crater with depths between 4 and 8 km. In this study, we observe that the recorded seismicity occurs in swarms as previous studies report), and we specifically identify four sequences that we characterize in detail via the first focal mechanisms available for this volcano. Our results suggest a change in the local seismicity distribution compared to earlier observations, which reported seismic activity near the volcano edifice associated with fluid migration along zones of weakness related to the extensional stresses of the Tepic-Zacoalco rift. The changes in seismic patterns and obtained focal mechanisms are consistent with observed fluid effects at many geothermal sites worldwide but also could suggest a resumption of activity at this volcano.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Unsupervised Classification and Displacement Estimation of Very-Long-Period Seismic Signals at Mount Marapi

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Very long-period (VLP) seismic signals are commonly observed in volcanic settings, indicating significant ground deformation events associated with magma movements, gas emissions, and caldera collapses. However, these signals which typically have frequencies around 0.01 Hz, are often overlooked since they fall outside the flat frequency response of most seismometers. For these frequencies, standard signal restitution from raw data can lead to noise amplification, distorting the original seismic signal. One alternative to this issue is the use of forward modelling to generate synthetic VLP seismic signals corresponding to various ground deformation scenarios, which can then be compared to the uncorrected seismic traces for identification. In this study, we analysed VLP seismic signals recorded at Mount Merapi prior to the phreatic explosion on April 27, 2018. Using the Dynamic Time Warping (DTW) algorithm, we performed an unsupervised classification of these signals and compared the classified data with synthetic traces to identify the most likely ground deformation responsible for the observed seismic waveforms. Additionally, to assess the effectiveness of our method, we examined the correlation between synthetic VLP traces representing different ground deformation scenarios and explored how, under certain conditions, these signals could be misinterpreted due to their similarity. Our method provides an alternative for systematic analysis of VLP signals in raw seismic data, overcoming issues of noise distortion. This enhances volcano monitoring, by enabling better understanding of volcanic deformation.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Detection and classification of pre-eruptive tilt changes for understanding immediate precursory processes of volcanoes

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Tilt changes sometimes precede volcanic eruptions and are essential for understanding the immediate precursory processes. Maeda (2023) identified 3,976 waveforms that included tilt changes before eruptions at ten volcanoes in Japan. We present subsequent surveys of detecting pre-eruptive tilt changes worldwide and classifying them based on waveform similarity to understand the mechanisms of tilt changes. We surveyed the official websites of monitoring agencies and reviewed papers to identify the times of 281 eruptions at 20 monitored volcanoes in seven countries with a 1-min temporal resolution. We downloaded broadband seismic records from the EarthScope, IPGP, and Geofon data centers and applied the same procedure as Maeda (2023) to examine tilt changes before each eruption. The analysis is in progress; so far, we identified pre-eruptive tilt changes in six waveforms at Pagan, Semisopochnoi, Kanaga, and Cleveland volcanoes. Combined with the tilt changes in Japan identified by Maeda (2023), we classified the waveforms based on a matrix of misfits between all waveform pairs. The results consisted of 75 groups with waveforms. We stacked the waveforms in each group and categorized them based on acceleration-deceleration patterns. Some groups showed acceleration that typically evolved to t^{1-2}, where t is time. Only two groups showed deceleration ($t^{<0.5}$). Mixed types, composed of acceleration followed by deceleration or vice versa, were the most frequent. This work was supported by JSPS KAKENHI Grant Number JP21H05203.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Seismic Noise as a Window into Volcanic Unrest: Observations from Ruapehu, New Zealand in 2022

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We applied Moving Window Cross-Spectral Analysis (MWCS) of ambient noise at Ruapehu volcano to monitor subtle temporal variations in the elastic properties during the March-June 2022 unrest episode. This unrest episode was significant, with temperature of the volcanic crater lake reaching 41°C, the strongest volcanic tremor since the 1995-1996 eruptive sequence, and SO2 emissions peaking at 390 tonnes per day. Our analysis revealed a ~0.5% decrease in relative seismic velocity at the beginning of 2022, coinciding with earthquake swarms. This correlation suggests that the process triggering the swarms may also be responsible for the observed velocity drop. A similar ~0.5% relative seismic velocity reduction was observed during the volcanic unrest in the East-North of the volcanic edifice. This seismic velocity drop appears to be a reversible process, likely driven by magmatic or fluid movement. Possible causes include the opening of fractures within the magmatic reservoir, fluid fluxes, magmatic anomalies/intrusion, or environmental factors (e.g. rainfall or atmospheric pressure changes) that could contribute to the formation of low-velocity zones. By mid-May, volcanic tremor and crater lake temperature began to decline, most likely due to a reduction in fluid circulation, possibly due to sealing processes. However, the reduction seismic velocity persisted, indicating potential ongoing subsurface alteration. This study highlights the importance of using ambient noise monitoring to detect seismic velocity changes during volcanic unrest. By providing a potential insights into subsurface processes, this method can complement current monitoring techniques and improving eruption forecasting and hazard assessment at Ruapehu.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Imaging lava eruptions and crater morphology changes at a basaltic volcano using infrasound

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Eruptions at continental basaltic volcanoes can take and combine various forms, including lava lake, lava flows and fountaining, explosions or structural collapses. Aside from a few well-instrumented cases, accurately reconstructing their precise processes and chronology is hampered by the lack of detailed visual observations in space and time. However, because they emit low-pitched sounds, called infrasounds, any changing and potentially hazardous eruptive activity can be inferred with specialised microphones. At Nyiragongo volcano (D.R. Congo), its flank eruption in 2021 was accompanied by the drainage of the world's largest lava lake modifying the acoustic resonance of the summit pit crater. Too low to be perceived by human ears, the excitation of resonance frequencies were recorded from local distance (0-20 km) up to Kenya (~800 km) and are interpreted in terms of the time-varying pit-crater geometry using acoustic numerical modelling. We also tracked lava fountaining and flows on Nyiragongo's flank by means of the emitted infrasound to get a consistent scenario of lava movements between crater and flank. This remarkable acoustic signature thus encoded the underlying mechanisms of a rare flank eruption, which could help to anticipate the next one.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Analyzing the 2022 Mauna Loa eruption sequence through the I59US infrasound array and how long-term detection monitoring can be beneficial in estimating the onsets of volcanic events.

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One of the biggest problems in geophysical monitoring, especially infrasound, is how to separate out the unwanted noise from the signal of interest. For infrasound specifically, there is an importance in knowing at which frequency ranges unwanted noise is generated and what location the noise is sourced from. Determining from where and at frequencies noise originates is of utmost importance. Here, we look at multiple years of data from the IMS infrasound station I59US in order to build a station history/profile to help detect, characterize, and locate the different phases of the 2022 Mauna Loa eruption sequence in Hawaii. The 2022 eruption began at 9:26 UTC on November 28 as a fissure opened in the summit caldera. Subsequently, multiple fissures began to erupt and migrated down the northeast rift zone by the start of November 29. The fissure eruptions along the northeast rift zone continued until December 9 when the eruption sequence came to a stop. Using detailed past infrasound data and detections, the assessment of background noise (e.g. source location, duration, timing, frequency content) is performed to obtain an understanding of when an eruption phase detection is possible or be encapsulated by undesired noise. Furthermore, using past data allows for the detection of eruption onsets to be visualized easier compared to only using detections from the moment of eruption. Additionally, this presentation uses data from other infrasound stations around Mauna Loa to compile an eruption history of the 2022 sequence though infrasound analysis.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Activity and focal mechanism of deep low-frequency earthquakes beneath Mt. Fuji revealed through waveform classification

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Deep low-frequency earthquakes (DLFs) are the earliest precursors of volcanic eruptions, and their monitoring is crucial for early disaster preparedness. Mt. Fuji exhibits the most frequent occurrence of DLFs in Japan, including relatively large events (M1–2). The hypocenters were located at 10–20 km depths, just above the high Vp/Vs zone. At the base of the hypocenter distribution, the inflation event occurred in 2008–2010. Following the 2011 Shizuoka Earthquake (Mw 5.9) near the northeastern edge of the hypocenter region of DLFs, the number of DLFs increased. This study systematically classified the waveforms of DLFs recorded between 2006 and 2022 to investigate their activity and focal mechanisms. Hierarchical clustering using correlation coefficients was applied to seismic data of DLFs. The analysis identified five groups (G1–G5): G1, G2, and G4 showed low-frequency (1–2 Hz) waveforms, while G3 and G5 included both low- and mid-frequency (3–8 Hz) waveforms. Hypocenter locations were slightly different between groups. G3 exhibited relatively steady activity and a high (~2) b-value. In contrast, G4 and G5, became more active after 2009 and 2011, respectively, and showed lower b-values (~1.5), indicating higher differential stress in their source regions. Focal mechanisms, estimated using S/P spectral ratios, had isotropic components possibly associated with fluid oscillation. These findings may indicate that increased differential stress, driven by magma supply linked to the inflation event and the 2011 Shizuoka Earthquake, triggered DLFs. Further studies are needed to refine waveform classification and focal mechanism estimation.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Full-Waveform Inversion of DAS data on a subglacial volcano: Grímsvötn, Iceland

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We present the results of an experiment with Distributed Acoustic Sensing (DAS) on the Grímsvötn volcano in Iceland, and the potential for Full-Waveform Inversion (FWI) with DAS for source properties and Earth structure. A 12 km long fibre-optic cable follows the caldera rim and ends near the central point of the caldera on top of the subglacial lake above Grímsvötn, where we acquired data for one month (May 2021). Grímsvötn is one of Iceland's most active volcanoes and is covered by the Vatnajökull ice cap. Here, we discover previously undetected levels of microseismicity, which we locate probabilistically with first-arrival times and the Hamiltonian Monte Carlo algorithm. The ~2000 detected events have local magnitudes between -3.4 and 1.7, and their locations indicate clear clusters of activity near surface expressions of the caldera fault, such as fumaroles and cauldrons. Combined with a starting model that includes the complex topography and ice sheet, we iteratively optimise the moment tensor components and refine the source locations of ~10 high-quality events in the frequency range of 1.5 – 3 Hz in an FWI workflow. This source inversion is followed by a proof-of-concept study that inverts DAS data for structure with FWI, showing small-scale velocity anomalies related to the geothermal activity of the subglacial volcano. The combination of state-of-the-art inversion techniques and DAS has the potential to model volcano-tectonic microseismicity and velocity anomalies in great detail, increasing our understanding of subglacial volcanoes and their geothermal dynamics.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Submarine volcano monitoring with Distributed Acoustic Sensing at Kolumbo, Greece.

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We present the results of an experiment with Distributed Acoustic Sensing (DAS) at Santorini and Kolumbo in Greece and the potential of DAS to augment existing seismic monitoring networks. Kolumbo is an active submarine volcano in the Aegean Sea, and its vicinity to the densely populated island of Santorini emphasises the need for continuous monitoring. A 45 km long fibre-optic cable connects the islands of Santorini and Ios, where we acquired data for two months (October – December 2021). Here, we discovered around one thousand events, using an automated earthquake detection algorithm that is based on image processing techniques. DAS reveals an approximate doubling in the number of events detected. Surprisingly, DAS detects many distant events of low magnitudes, while it also misses several larger and nearby events that the existing network does record. Manually picked first arrivals are combined with a travel-time look-up table based on a 1D velocity model to conduct a grid search to locate the events. The ability to locate events depends heavily on the fibre layout and source location, which we verify with synthetic tests. Finally, we compare the performance of DAS to the existing seismic network to locate events, showing that the addition of DAS can refine the event localisation. The results of our experiment highlight the potential of DAS to complement existing monitoring networks to study active submarine volcanoes by locally lowering the detection threshold of a network and decreasing the uncertainty in the event locations.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

A preliminary investigation of the Mountain Baekdu Volcano Seismicity

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Mountain Baekdu (Changbaishan) is an active volcano at the border between China and North Korea. The eruption in 946, also known as the Millennium Eruption, was one of the most violent volcanic events in recorded history. The eruption is classified as a VEI (Volcanic Explosivity Index) 7 and is suspected to be responsible for significant climate change in Northeast China and its vicinity. Historical records, including the Goryeosa and Heungboksa Temple History, describe phenomena such as “heaven’s drum thunder” and ashfall resembling snow on November 3, 946. Reports suggest a series of eruptions from 944 to 947. This study reviewed the seismicity in the mountain Baekdu since 1993. The volcano earthquake catalog includes earthquakes as low as magnitude -0.5. A statistical analysis indicates the earthquake catalog is complete to magnitude 0.3. There was a period of high seismicity between 2002 and 2005, reaching a climax in November 2004 with the largest earthquake with a magnitude of 3.7. The b-values of the frequency-magnitude distribution of the earthquakes of the entire period and the high-seismicity period are approximately 0.71 and 0.73, respectively. The b-values are lower than the global mean (~ 1) and lower than those observed in many volcanic regions. The low b-values indicate the earthquake catalog is far from complete and requires further investigations to include smaller events. There are large temporal variations in seismicity. The high-seismicity period approximately coincides with the occurrence of the magnitude 7.3 earthquake (focal depth at ~566 km) on June 28, 2002.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Comparing seismoacoustic signals and volcanic emissions from the 2023 explosive eruption sequence of Shishaldin Volcano, Alaska

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Between July 14 and November 3, 2023, Shishaldin Volcano, Alaska produced a series of 13 explosive eruptions locally monitored by three seismic and infrasound stations. The eruptions are notable for their relative similarity in seismic and infrasound amplitudes and spectral properties in the hours to days prior to the paroxysmal phases. These trends were used to monitor the eruption in real-time and help issue eruption forecasts. The eruption also produced significant volcanic ash clouds that impacted air traffic and local communities in the region. Here we compare the coeruptive seismic and infrasound signals with the volcanic emissions from the 13 explosive eruptions of Shishaldin. In particular, we investigate the seismic energy and reduced displacement between events and discuss possible physical processes that may explain their seismic similarities. Although factors such as elevated wind noise make infrasound data more challenging to analyze, we identify relationships between RMS pressure across the 13 eruptions. We compare the seismoacoustic parameters with volcanic emissions measurements for each event, such as SO2 mass, plume height and onset time as observed by satellite and webcam analysis. Preliminary results suggest a positive correlation between plume height and RMS pressure and reduced displacement, particularly among later events. The comparison of geophysical data and volcanic emissions can provide insights into the physical processes within, as well as improve eruption monitoring and forecasting for, Alaska and global stratovolcanoes like Shishaldin.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Seismic Signal Analysis and Temporal Sequencing of Mud Ejections in Dayoukeng, Northern Taiwan

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Dayoukeng is the most active gas emission and seismically active area within the Tatun Volcano Group, warranting intensive monitoring. Nodal seismometers Zland were deployed to compare seismic signals during anomalous activities. Between late 2021 and early 2022, significant mud-ejected material was observed near the main vent. Geochemical analyses indicated an abnormal increase in cation concentrations in the hot spring at the end of 2021. Real-time webcam data revealed additional steam activity above the main vent, suggesting intensified gas emissions that may have led to a small-scale event. Short-period seismic data from the nearby main vent revealed several stages of signal characteristics, potentially linked to changes in steam activity: 1. Initial Increase: An uptick in microearthquakes at Dayoukeng. 2. Marked Intensification: A substantial rise in signals with complex waveforms comprising seismic and high-frequency acoustic waves lasting several hours. 3. Major Mud-Ejection Phase: Low-frequency microtremors associated with significant mud ejection. 4. Recurrent Composite Signals: Multiple episodes of composite seismic and acoustic wave signals, each persisting for hours. 5. Activity Decline: A sharp decrease in signals, indicating a slowdown in activity. Following the event, recent observations have detected similar mud ejections in Dayoukeng, suggesting state changes that indicate increased regional activity and facilitate the emission of mud. The seismic data from the dense short-period network clearly delineate the temporal sequence of this event, enhancing the understanding and modeling of overall activity in Dayoukeng.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

The 11 July 2024 Paroxysm at Stromboli Volcano, Italy: A Multidisciplinary Study of Pre-Eruption Unrest and Dynamics

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Stromboli Volcano (Italy) is known for its persistent degassing and moderate summit explosions, with occasional powerful paroxysms. These sudden and intense explosive events represent the primary hazard associated with open-vent volcanoes. This study investigates the geophysical activity at Stromboli during early July 2024, leading to the paroxysmal eruption on July 11. We integrate seismic, infrasound, and ground deformation data with visual observations and Uncrewed Aircraft System (UAS) imagery to characterize the precursory signals and eruption dynamics. Our analysis reveals heightened volcanic tremor and Very Long Period (VLP) seismicity, accompanied by moderate explosions, lava effusion, and minor collapses at the North summit crater. On July 4 at 12:16 (UTC), a major explosion triggered collapse activity at the northern summit craters, lasting until July 7. Concurrently, effusive vents appeared along Sciara del Fuoco's northwest flank. The unrest climaxed with a sudden eruption on July 11 at 12:08 (UTC), preceded by a rapid ground deformation signal about 10 minutes earlier. This event generated a 5 km-high eruptive column and pyroclastic density currents descending Sciara del Fuoco. We interpret the sequence as driven by the ascent and eruption of shallow-resident magma, followed by conduit drainage and the subsequent injection of gas-rich magma that triggered the July 11 explosion. The rapid inflation observed prior to the paroxysm highlights the critical role of gas accumulation and release within the volcanic conduit. This paroxysm aligns with previous explosive events at Stromboli, offering renewed insights into the precursory processes and eruption mechanisms specific to this volcano.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Submarine caldera collapse during the 2022 Hunga-Tonga eruption highlighted by seismic T-waves

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Emile Okal[2] Rennie Vaiomounga[3] Mafoa Penisoni[3] Daisuke Suetsugu[4] [1]*School of Environment, Waipapa Taumata Rau | The University of Auckland, Auckland, New Zealand* [2]*Department of Earth and Planetary Sciences, Northwestern University, Evanston, IL, USA* [3]*Geology Unit, Natural Resources Division, Ministry of Lands and Natural Resources, Nuku'alofa, Tonga* [4]*Japan Agency for Marine-Earth Science and Technology, Yokosuka, Kanagawa, Japan* Submarine volcanic eruptions are a known source of destructive near-field tsunami. The 2022 Hunga-Tonga eruption produced waves with run-up heights of almost 20 metres at islands over 60 km distant, although the exact wave generation mechanism has so far remained elusive. To better understand and define tsunami genesis, this study focussed on the hydro-acoustic records of stations across the SE Pacific. Seismic tertiary waves (T-waves) result from on-land conversion of hydro-acoustic into seismic energy, which makes them an insightful proxy for underwater processes. We observed a sequence of such T-waves, which can be traced back to a coherent source near the volcano. This event coincided with a significant drop of the eruption plume and the origin time of the tallest tsunami to hit the island of Tongatapu (Kingdom of Tonga), which were both attributed to a caldera-collapse at the volcano. Hydro-acoustic emissions, which travel faster than tsunami waves, and associated T-waves from this event may therefore not only serve as a proxy for a violent and tsunamigenic process occurring at the volcano, but also as a tool to provide some warning time ahead of the incoming tsunami waves.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Spatiotemporal Analysis of an Earthquake Swarm beneath the Dayoukeng, Tatun Volcano Group, Taiwan

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The Dayoukeng fumarole, situated within the Tatun Volcano Group (TVG) in northern Taiwan, represents one of the most active hydrothermal systems in the region, characterized by vigorous fumaroles, hot springs, and phreatic deposits. The persistent seismicity observed beneath this area over past decades suggests ongoing hydrothermal processes. Its proximity to the densely populated Taipei Metropolitan Area (population > 7 million) underscores the importance of comprehensive volcanic monitoring. To enhance our understanding of the subsurface processes, we deployed a high-density seismic array of 50 Fairfield Nodal ZLand 3C nodes around Dayoukeng, with inter-station spacing of 50-200 meters. This array recorded a significant earthquake swarm on December 21, 2021, initially comprising approximately 50 events detected by the Tatun Volcano Observatory at Taiwan (TVO) permanent broadband network. Analysis of the dense array data revealed additional micro-earthquakes within the swarm sequence. The detailed spatiotemporal distribution of seismicity and focal mechanism solutions illuminate the complex interaction between hydrothermal activity and structural features beneath Dayoukeng. These findings advance our understanding of the volcanic system's current state and contribute to volcanic hazard assessment for the Taipei Metropolitan Area.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Exploring seismic events on La Réunion: An analysis of rotational sensor and array source directions

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Indian Ocean island La Réunion hosts the shield volcano Piton de la Fournaise, which lastly erupted in 2023. Besides pre- and co-eruptive signals like volcano-tectonic (VT) earthquakes and eruption tremor, (very) long period events along with rockfalls are seismically recorded. In 2022 we co-installed a rotational sensor to a permanent station of the monitoring network of the Observatoire Volcanologique du Piton de la Fournaise (OVPF) and set up an array of seven additional seismometers within the Enclos-Fouqué caldera. The objective is to compare directions obtained by array processing and new methods using the rotational sensor to the locations from the OVPF's network. To obtain source directions (back azimuths), we apply beamforming on the array data of the vertical component, calculate an orthogonal distance regression between the two horizontal rotational sensor components or determine the correlation between the vertical rotation rate and the horizontal acceleration. We use 37 different events recorded on all instruments and compare the respective calculated back azimuths (BAz) of the array and rotational sensor to the OVPF network catalog location. First results indicate better array than rotational sensor BAz for local earthquakes with respect to the reference direction from the OVPF. For volcanic summit earthquakes however, array and rotational sensor BAz results mostly fall both close to the reference, pointing to the main crater Dolomieu. We assume stronger events generally leading to better source directions and consider topography and local heterogeneities as a cause of diverging results. Following analysis will also include rockfalls as well as thunderstorm events.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Link between inner crater collapses, plume events and transient signals during the 2021 Geldingadalir eruption

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After 781 years of volcanic quiescence, the Geldingadalir eruption started in March 2021 on the Reykjanes Peninsula in southwest Iceland. Several seismometers and acoustic sensors located across the peninsula, recorded volcanic tremor generated by the eruption. In early May, the tremor pattern shifted from continuous to episodic, characterised by minute-long episodes followed by periods of repose. However, by mid-June, the continuous tremor reappeared but ceased abruptly in early July when the lava pond in the active crater drained completely. Two hours after the draining, a huge dark plume and a few smaller plumes appeared, which were accompanied by transient seismic signals and six distinct acoustic signals, whose peak tends to arrive before the seismic signal peak. After these plume events, the duration of tremor increased significantly, with episodes lasting for hours rather than minutes. Here, we study the role of these plume events in this tremor transition and analyse the cause of the seismic events and the plume events in detail. To analyse the seismic events, we performed a source inversion using seismometers within a 6 km radius of the active crater and tested different source models, including moment tensor and single force models. Additionally, we calculated a decreasing Volcanic Acoustic-Seismic Ratio (VASR) with time from the seismic and acoustic signals and we will discuss its potential interpretation. Using video data from local webcams, we analyse potential causes of these plumes, and we investigate a possible link between the observed plumes and the transient signals.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Acoustic and SO2 monitoring at Sakurajima volcano

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Sakurajima is one of the most active volcanoes of Japan, with multiple explosive events every month. The types of explosions can vary greatly in magnitude, duration and ash content. Acoustic monitoring, particularly in the infrasound range, has proven a valuable tool to monitor the magnitude and duration of explosive events, however estimating mass eruption rate remains challenging. Further investigation is thus needed to understand the sound producing mechanisms of these events, and extract eruption source parameters from acoustic data. Here, we report the results from a 4-week infrasound monitoring campaign at Sakurajima in November 2024. Two 4-element arrays were deployed at ca. 3-4 km distances from the active vents. We also routinely measured SO_2 emission rates using a UV camera, but temporal resolution was limited due to the weather conditions. Volcanic activity during the campaign consisted of quiescent degassing (i.e. without explosive activity) from both active vents (Minamidake and Showa) as well as a handful of small ash-laden explosions from Minamidake. I will present the infrasound data from these events, alongside possible interpretations using a jet noise model. I will also discuss the role of laboratory experiments and numerical modelling in shedding light on volcanic infrasound generation mechanisms and improve ash forecasting.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Towards deciphering the origins of seismic tremor signals recorded in the Askja volcano region, Iceland

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We analyze seismic data from 39 seismic stations operated by two different institutions (Icelandic Meteorological Office and University of Cambridge) to document tremor episodes repeatedly recorded in the Askja region of Iceland over the past 18 years (2007–2024). The stations form a network with an aperture of around 100 km, centered on the Askja volcano. Tremor episodes are automatically detected and located by analyzing the eigenvalues and first eigenvector of the seismic network covariance matrix, respectively. Observed spatio-temporal tremor characteristics are compared with river discharge from Vatnajökull glacier, Hálslón reservoir elevation, and local seismicity. Preliminary results suggest the presence of distinct tremor patterns associated with different origins, with three main clusters. A first cluster of shallow co-eruptive tremor of magmatic origin is associated with the 2014–2015 Bárðarbunga Holuhraun eruption. A second cluster of tremor is persistent throughout almost the entire period in the 2–5 Hz frequency range, with sources located along the Jökulsá á Fjöllum river and mainly distributed between the surface and 2–3 km depth, possibly affected by seasonal changes in meltwater dynamics. A third cluster of weeks- to months-long tremor episodes containing lower frequencies down to 1 Hz, distributed throughout the transcrustal range at the top of the eastern end of the deep (13–19 km) 2007–2008 Upptyppingar magma intrusion, is possibly controlled by delayed poro-elastic effects induced by loading/unloading cycles of the Hálslón reservoir. Our observations highlight overlapping tremor-generating mechanisms in the Askja region and show the importance of careful signal characterization to improve monitoring capabilities.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Pre-existing structures control the orientation of strike-slip faulting during the 2021 Fagradalsfjall dike intrusion

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The 2021 Fagradalsfjall dike intrusion marked the initiation of a new era of volcanism on Iceland's Reykjanes Peninsula. In this study, we present a large automatic catalog consisting of more than 80,000 earthquake hypocenters spanning the full period of the dike intrusion, which were derived from seismic data recorded by a dense network of seismic stations. The 9 – 10 km long dike exhibits a two-segment geometry of similar lengths. Linear regression on a relatively relocated subset of over 12,000 earthquakes revealed a strike of 029° with a standard deviation of 2° in the southern segment, and 046° with a standard deviation of 1° in thenorthern segment of the dike. A total of 97 detailed fault plane solutions from relative relocations of selected subsets of events provide new insight into the controls on faulting, showing almost exclusively right-lateral strike-slip/oblique-slip faulting associated with the dike intrusion, and a lack of left-lateral strike-slip fault motion. The alignment of fault planes is consistent with the orientation of pre-existing fractures, within uncertainty estimates. In light of these observations, we conclude that the likelihood of faulting being related to classical dike tip fracture of new rock ahead of the dike tip is low. Instead, our preferred explanation for the dominant controlling factor on the orientation of dike-related faulting is the extensive network of pre-existing fractures formed by the active transtensional plate boundary along the Reykjanes Peninsula.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Multi-parametric recording of multi-vent activity at Stromboli volcano (Italy)

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Strombolian activity often occurs from adjacent vents, providing a good opportunity for understanding shallow conduit processes. In October 2023, Strombolian activity at Stromboli was occurring from three vents, with one displaying ash-rich explosions (S vent) and two others (N1_1 and N1_2), 10-20 meters apart and often erupting almost simultaneously with ash-poor explosions and spattering (at N1_2). Over four consecutive days we recorded the activity of the three vents with the SKATE (Setup for Kinematic Acquisitions of Transient Eruptions) apparatus, which includes a high-definition high-speed camera recording 30 seconds-long videos at 250 frames per second (FPS), a thermal infrared camera continuously recording at 16 FPS and a broadband microphone continuously recording at 20 kHz. The thermal recording provided a continuous record of the activity at all vents, represented as peaks in the brightness temperature in a specific control area. The high-speed camera focused on the N1 twin vents, which were also the only ones producing sound. From the high-speed videos and the microphone we obtained the exit velocity, size and number of the pyroclasts and the amplitude and mean frequency of the acoustic radiation of the explosions, respectively, as well as the ejection onset to acoustic arrival time delay. Among the several correlations that characterize the explosion parameters, most interesting is the direct correlation in the kinetic energy of the total ejecta from N1_1 and N1_2 for joint eruptions, pointing to a common shallow pressure source that, despite vent-specific differences, kept a constant ratio of energy partitioning between the vents.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Local, regional, and distal recordings of seismic unrest at Taʻū Island volcano, American Samoa

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A seismic swarm near Taʻū Island, a volcanic island in eastern American Samoa, occurred from July to October 2022. The earliest unrest was noted as felt shaking reports in late July. The U.S. Geological Survey Hawaiian Volcano Observatory responded by installing temporary and then permanent seismometers to monitor the activity. This network variability made it difficult to characterize the earliest seismicity and contextualize the entire sequence to discriminate between an underlying tectonic or volcanic source. We analyze hydroacoustic detections from a hydrophone array near Wake Island, 4500 km northwest of Taʻū Island volcano. Using least-squares beamforming analysis, we create a catalog of *T*-wave detections from the direction of Taʻū Island to track the earthquakes. Both the rate and hydroacoustic pressures, which we interpret as a proxy for earthquake size, gradually increased from late July to August, peaking on August 19 (rate) and August 24 (size), before decreasing to background in late September. Minutes-long bursts of tremor were also recorded as local network data became available August 20. Tremor activity increased, peaking on August 25, before ending in early September. Bursts were band-limited to ~1-5 Hz and recorded as *S* waves at a regional station 250 km away. Our results do not constrain the tremor locations, but comparisons of earthquake and tremor reduced displacements recorded locally and regionally suggest a deeper tremor source. We interpret the increase in earthquake size and rate, together with the occurrence and relative depth of the tremor to reflect magmatic activity beneath Taʻū Island volcano.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Rapid characterization and relocation of remotely monitored seismic unrest for improved eruption forecasting using global seismic data

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Many of the world's volcanoes remain unmonitored seismically at local distances, posing significant challenges for eruption forecasting and monitoring of unrest. Together, the U.S. Geological Survey's National Earthquake Information Center (NEIC) and Volcano Disaster Assistance Programs (VDAP) are addressing this problem in several ways. We are using regional and teleseismic data from the Global Seismographic Network and other publicly available networks, coupled with advances in detection and analysis methods to: 1) extend earthquake source detection methods, typically focused on high-frequency body waves, to lower frequencies using back-projection methods to improve detection of remote volcanic sources, 2) develop and deploy double-difference relocation methods using both body and surface waves to improve locations and therefore better resolve volcanic processes (e.g., diking), and 3) search global earthquake archives for historical analogs to better interpret seismogenic processes, statistically assess eruptive outcomes, and improve forecasts. Combined, these efforts are improving our ability to rapidly characterize seismic unrest at remote and unmonitored volcanoes. We present several recent examples where we have applied these methods, including the January 2022 eruption of the Hunga Tonga-Hunga Ha'apai volcano (Tonga), the October 2023 submarine eruption of Sofu Seamount (Izu Islands, Japan), the May 2021 eruption of Mount Nyiragongo (Democratic Republic of the Congo), and the ongoing dike intrusion between Fentale and Dofen volcanoes (Great Rift Valley, Ethiopia).

Theme: 3. Volcanic processes

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Imaging volcanoes during unrest: Nodal Ambient Noise Tomography of a transient plumbing system, Vulcano, Italy.

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Volcanic risks increase exponentially during periods of unrest, with challenges in distinguishing between magmatic intrusions and hydrothermal activity as primary drivers of volcanic reawakening. This uncertainty has implications for risk mitigation strategies, affecting civil protection decisions and evacuation plans. In late 2021, Vulcano, Italy, entered into a phase of unrest featuring unprecedented very long period (VLP) seismic events, usually associated with magma and gas flowing through shallow volcanic conduits. Current causative models explaining such events remain non-unique, advocating either magmatic or hydrothermal activity. To investigate the source of deformation, we use the Nodal Ambient Noise Tomography (NANT) method to generate high-resolution shear-wave velocity (Vs) images that help discriminating the distribution of magmatic and hydrothermal drivers of unrest. We use continuous seismic data from a dense local network of 196 three-component short-period geophones (250 Hz sampling rate) deployed for one month (October-November 2021) during Vulcano's unrest. The inverted 3-D Vs model indicates structures relating to the volcanic edifice and point out the geometries characterising the shallow plumbing system of Vulcano. The implementation of NANT during unrest offers promising capabilities to unravel the velocity structure of dynamic and deforming volcanic regions. This methodology, if efficiently and rapidly processed and explored towards (near) real-time monitoring applications, has the potential to lead to the development of dynamic and adaptive evacuation plans. These advances would contribute to more effective and source-dependent risk mitigation schemes in volcanic regions that may ultimately save lives.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Characteristic of the 2023-2024 Eruption of Marapi Volcano

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After a 5-years repose, Marapi Volcano in West Sumatra, Indonesia, erupted in two distinct phases. The first phase, spanning January to February 2023, was marked by a series of small explosions and degassing event. After a 9-months quiescence, the second phase began with a major explosion on 3 December 2023, tragically claiming the lives of 24 hikers. This eruption phase continued for over a year, featuring combination of vulcanian and strombolian activities. During the first phase, explosions were initially frequent, occurring almost hourly, but their intervals gradually lengthened until activity ceased a month later. Early explosions produced simple seismic waveforms and high infrasound amplitudes (> 50 Pa peak-to-peak) at the summit station located 300m from the vent. Over time, the explosions became weaker, with smaller amplitude and more oscillating coda. In contrast, the second phase has longer interval but more violent explosions, some exceeding the dynamic range of infrasound sensor located 5km away. In the hindsight, precursory seismic swarms were observed before both eruption phases. In September 2022, earthquakes clustered 4-5km NW of the crater at depth of 2-4km, migrating to shallower depths beneath the active vent. Similar seismic patterns were recorded a few months before the second phase. Tiltmeter data from summit and flank stations indicated a migrating pressure source, suggesting the magma pathway may influenced by the regional fault system. However, estimating the exact time when Marapi will enter an eruption period is still a challenge to this day.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Seismoacoustic analysis of possible vent-drying sequence during phreatomagmatic activity on 13 July 2021 at Semisopochnoi Island, Alaska

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Semisopochnoi Island in the Aleutian Arc, Alaska, erupted from 2018 to 2021. The activity occurred at the north crater of Mount Young and was characterized by phreatomagmatic eruptions with low-level ash emissions (Orr et al., 2024). Here, we focus on small amplitude (up to 0.2 Pa at 5 km from the crater) pulse-like infrasound observed on 13 July 2021. Pulse-like infrasound sometimes suggests interaction with water at the vent, for example, shallow submarine eruptions (Lyons et al., 2019). Indeed, overflight observations confirmed a small, ephemeral water lake on the crater floor in June 2021. We examined temporal variations in seismoacoustic amplitudes and spectral characteristics to discuss transitions of the source dynamics. We also picked pulse-like infrasound events by template matching and investigated their waveform, spectra, and temporal change in event number. The seismoacoustic amplitude ratio decreased, and the infrasound frequency index (Fee et al., 2020) increased with time. With this change, pulse-like infrasound activity became intermittent and finally waned. These results suggest less interaction with water due to drying out of the vent. Satellite observations also show weakened steaming from the crater and increased ground surface temperatures inside the crater from 13 to 14 in July. The pulse-like infrasound exhibits different waveform and spectrum among stations, which are stable over time at each station. These features could not be explained by source characteristics alone. In the presentation, we discuss the possibility of topographic effects based on simulations and consider the source process of pulse-like infrasound.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Trapdoor Faulting and Initiation of the 2018 Eruption at Sierra Negra Volcano, Galápagos Islands

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At the basaltic calderas of the western Galápagos Islands, large intra-caldera earthquakes have been commonly observed closely preceding eruption onset. The nature of earthquake-eruption interaction likely plays a role in eruption initiation, yet the specific mechanisms remain enigmatic. Here we analyze microseismicity to show that the initiation of the 2018 eruption of Sierra Negra involved a complex cascading process lasting over ten hours. The co-seismic stress changes from a Mw 5.4 trapdoor faulting earthquake did not immediately promote failure of the magma reservoir, as happened for the 2005 eruption. Instead, the emergence of repeating long-period earthquakes (LPs) families indicates a cryptic phase of reservoir failure, ultimately culminating in dyke propagation and eruption. Our results indicate that a primed magmatic system and favorable co-seismic stress changes may not be sufficient to cause reservoir failure and suggest that such eruptions can be harder to forecast than currently thought.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Estimating magma ascent rates using volcano seismicity

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Particularly in silicic volcanic settings, the magma ascent rate is an important factor controlling the type of eruptive behaviour. As magma ascends it generates low-frequency earthquakes if a certain threshold in shear stress is reached and magma in glass transition can fail in a brittle manner. This leads to the generation of low-frequency earthquake swarms of similar waveform if the failure mechanism is repeatable, and the earthquake location remains approximately constant. Many silicic volcanic systems show this behaviour. This contribution explores several ways of linking low-frequency earthquake swarms directly to magma ascent rates for the purpose of predicting eruptive behaviour. We analyse the uncertainties imposed by the estimation of seismic amplitude, conduit geometries and magma properties on such predictions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Investigating volcanic tremor and long-period seismic events through experiments on porous media gas flow

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Volcanic tremor and long-period (LP) events are seismic signals thought to be associated with the circulation of magma and/or hydrothermal fluids. According to the gas pocket model by Girona et al. (2019), gas accumulating beneath permeable caps in shallow conduits can trigger spontaneous pressure oscillations that produce tremor and LP events. However, analytical solutions are not available to capture scenarios dominated by inertial effects (Forchheimer's law), and comparisons of seismo-acoustic signal with and without permeable caps (e.g., bubbly flow) remain limited. To address these gaps, we designed an experimental setup that simulates gas-driven volcanic seismo-acoustic signals. The system comprises a vertical cylindrical pipe (4 cm i.d.) containing, from the bottom to the top, water, an air pocket, a permeable cap, and an upper section open to the atmosphere. Air is injected at the pipe's base through flow meters, while we measure pressure in the air pocket beneath the cap, record vibrations (acceleration), and capture pressure signals above the cap with a microphone. Preliminary results show that water-only flow generates low-frequency (<1–5 Hz) pressure oscillations in the free air, with an acoustic peak near ~150 Hz, suggesting a Helmholtz resonance. In contrast, adding a porous medium above water and gas pocket yields pressure oscillations up to ~100 Hz and acoustic peaks at 0–1 Hz, indicating combined effects of water flow and porous media. Scaling analyses will allow comparing results with natural scenarios accounting for varying conduit diameters and viscosities, aiming to improve the interpretation of signals in real settings.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Gravity study of the Casamicciola area (Ischia Island, Southern Italy)

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Ischia Island, in the Gulf of Naples, is a key site for studying the interplay between volcano-tectonic processes, seismicity, and geothermal systems. Its geodynamic evolution, driven by the resurgence of Mt. Epomeo following to the Green Tuff eruption (60-56 ka), is characterized by magmatic intrusions, about 900 m of uplift, and an active geothermal system. The island's northern sector, however, faces high seismic risk, highlighted by the destructive 1883 and 2017 (Mw 3.9) earthquakes linked to the Casamicciola fault. This fault, with its shallow seismogenic sources and complex geometry, is central to local seismic hazard. A new gravity survey added 78 stations to the historical data, yielding a high-resolution dataset of ~16 sites/km^2 around the fault. Free-Air and Bouguer anomaly maps reveal significant horizontal density variations associated with subsurface structures. Edge analysis techniques, (e.g., Enhanced Horizontal Derivative, EHD), allowed the detection of structural features and the localization of horizontal density contrasts. A constrained 3D inversion, incorporating borehole data, geophysical models, and results of gravity data analyses, was applied to develop detailed density models of the fault system. Preliminary results constrain the fault's geometry and provide knowledge to study its interactions with geological and geothermal processes.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Improved detection of seismicity at Cordón Caulle (2011-12) using multiple machine learning approaches

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The 2011-12 Cordón Caulle, Chile, eruption provides the best case study of seismic data spanning a silicic eruption case study for understanding silicic volcanic system dynamics. Despite significant insights from seismic data, questions remain regarding eruptive dynamics, magma intrusions, precursory seismicity patterns, and tectonic-magmatic interactions. This study applies machine learning techniques for seismic event detection (VT and LP) and location. Our workflow integrates three deep learning phase-pickers (GPD, PhaseNet, EQTransformer) and dual phase associators (GaMMA, PyOcto), combining probabilistic detection with nonlinear location methods to reveal refined spatiotemporal patterns throughout the eruption sequence. Analysis of over 6,000 relocated events shows systematic variations in hypocenter distributions across eruptive phases, extending the recognized unrest duration from 5 to 8 months and tripling event detection compared with manual catalogs. Enhanced detection reveals peak rates of 900 events per day compared with 140 in conventional catalogs. We identify complex precursory swarm sequences and spatial correlations between seismicity and InSAR-derived deformation sources. This refined analysis, integrated with geodetic observations, provides new perspectives on fluid dynamics on the hydrothermal system, magmatic processes and volcano-tectonic interactions during silicic eruptions. Our results demonstrate machine learning's value in extracting additional insights from monitoring data, with implications for volcanic hazard assessment

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Increasing seismic activity within the intraplate volcanic system of Ljósufjöll in Western Iceland.

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A significant increase in earthquake activity was noted in 2021 in a tight cluster within the Ljósufjöll volcanic system, one of three volcanic systems of the Snæfellsnes Volcanic Zone in Western Iceland. The activity continued at a similar rate in 2022 and 2023 but increased in August 2024, with the largest event, of magnitude 3.2, recorded on December 18th 2024. The hypocentral depths of the earthquakes are 15-20 km. Most of the located earthquakes are typical volcano-tectonic events, with high frequency and clear S-waves. They are likely caused by brittle fracturing of rocks. They do occur, however, at considerable depth below the typical brittle-ductile transition for usual tectonic strain rates, which in Iceland is normally at 6-10 km depth. The earthquakes occur in an area of minimal tectonic strain rate within the North American Plate. Magma movements are therefore the most likely cause of brittle fracturing at this depth. Bursts of continuous tremor were detected in the area in December 2024-January 2025, further strengthening the interpretation of magmatic origin of the activity. Events located within these bursts are at similar depths as before. As of January 2025, no surface deformation has been detected in the area. Previous activity resembling this earthquake sequence include seismicity accompanying the 1973 Heimaey eruption and the deep dike intrusion at Upptyppingar, north of Vatnajökull, in 2007-2008. The latest eruption in the Ljósufjöll Volcanic System occurred in the tenth century CE. The monitoring effort has been increased in the area with additional seismic and GNSS instruments.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Precise relocation of volcanic-tectonic events recorded during the 2017-2019 swarm below the Chiles - Cerro Negro volcanic complex (Ecuador - Colombia)

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The Chiles - Cerro Negro volcanic complex (CCNVC), located in the Western Cordillera, on the Ecuador - Colombia border, has presented an increase in its seismic activity levels since 2013. This activity has been characterized by the presence of intense swarms of volcano-tectonic events. To examine the seismicity in the CCNVC area, we took as a sample, the swarm recorded between 2017 and 2019. As the rate of earthquakes in the area is high, we used automatic algorithms for the detection and picking of transient events, which were subsequently correlated with each other to group them within families of similar events using cross-correlation. This technique allowed us to locate approximately 43000 earthquakes grouped in 30 families. These preliminary locations allowed to select the best quality events and pipe them to a relocation process using double difference techniques. The precise relocations obtained for the first 5 families show complex sub-horizontal structures, with shallow depths between 0 to 2 km b.s.l, and reveal a lack of seismicity below 10 km below the edges. This could suggest the presence of a hot and ductile crust or a diffuse magma storage region. Besides, the spatio-temporal evolution of the seismicity of these families show horizontal migrations, which suggests changes in pore pressure in the subsurface, under the southern flank of the Chiles volcano, due to new pulses of volcanic activity in the area.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Repeated dike injections beneath the Sundhnúkur crater row, Reykjanes Peninsula, Iceland, imaged by relatively relocated seismicity

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Between November 2023 – January 2025 there have been eight dike intrusions and seven fissure eruptions beneath Sundhnúkur, on the Reykjanes Peninsula, Iceland. Geodetic and geochemical analyses show that these have been fed by a common source, located at 3-4 km depth beneath the harnessed Svartsengi geothermal area. This remarkable sequence of magmatic activity has been marked by abundant seismicity. Relative quiescence on the Peninsula following the July-August 2023 Fagradalsfjall eruption was interrupted in late October by elevated seismicity and surface uplift measured at Svartsengi, 8 km further west. As during inflation episodes at Svartsengi in 2020 and 2022, intense shallow seismicity accompanied the deformation, dominantly consisting of strike-slip faulting above an inferred sill. From around 15:00 on 10th November 2023, intense migrating seismicity and rapid metre-scale horizontal deformation marked the intrusion of a NNE-SSW oriented dike, which reached approximately 15 km length in just 8 hours, and propagated under the town of Grindavík, which was evacuated. On 18th December, similar (though smaller amplitude) signals marked a second, smaller intrusion, but in contrast this dike quickly breached the surface and culminated in a 4 km long fissure eruption. A similar pattern has repeated in the following 12 months, with cyclical re-inflation beneath Svartsengi, and repeated dike intrusions and fissure eruptions along a common lineament. Through analysis of high-resolution relative relocations of the dike-induced seismicity, we investigate the relative geometry of the repeated dike intrusions, and the relationship between the seismicity and distribution of dike opening and location of eruption onset.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

The Gridavík 2023 dyke and graben formation and growth imaged by seismic and geodetic monitoring

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The current volcanic unrest on the Reykjanes peninsula began in March 2021, when a fissure eruption occurred in the area of Fagradalfjall, and was followed by two further eruptions from the same volcanic dyke in the following two years. All these events were preceded by intense seismic swarms and were accompanied by surface deformation indicating extension and vertical movement. In autumn 2023 the seismic activity moved westwards - to the Grindavík/Svartsengi area, where an intensive seismic swarm activated the Reykjanes oblique rift zone. On 10 November the seismicity highlighted a narrow NE trending zone of about 15 km in length, which was accompanied by rapid subsidence resulting in the formation of a graben 9 km long and up to 4 km wide. The subsequent seismic swarm gradually diminished until 18 December 2023, when the eruption of Sundhnúkur began, starting a subsequent series of eruptions of the same dyke. We carried out precise hypocentre locations of the seismic swarms in the period ěř October - 18 November 2023 and analyse its space-time distribution. We find a bilaterally propagating tensile rupture of dyke-like character. Comparison with surface displacements measured by the GPS network shows that dyke growth derived from seismic migration is closely correlated with graben-related surface displacements. The character of earthquake focal mechanisms varies along the dyke and correlates with graben occurrence. We also propose a model linking the volcanic and tectonic drivers of the Reykjanes Peninsula extension.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

The Raspberry Shake infrasound and seismic sensors offers new perspective for volcano research and monitoring

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Raspberry Shake (RS) has developed affordable seismometers and acoustic sensors integrated with Raspberry Pi technology. These devices are smaller, lighter and approximately ten times cheaper than traditional instruments, reducing logistical challenges and making them ideal for deployment in remote and rugged environments such as active volcanoes. We tested RS sensors on Yasur Volcano, an ideal site for evaluating new instruments due to its high levels of Strombolian activity and easy access to the crater rim. This accessibility allowed us to install RS sensors at varying distances from the crater and confirm the volcanic origin of RS signals with thermal video recording from the crater rim. We identified four main active vents with distinct manifestations: two exhibiting Strombolian explosions, one with regular ash venting, and a fourth with nearly continuous gas puffing. The RS seismic sensors successfully detected the Strombolian explosions, with the optimal performance observed when the sensors were positioned at the base of the volcanic cone rather than at the crater rim. Continuous gas puffing was reliably recorded at distances up to at least 400 meters from the crater. However, at 2 kilometers, background noise obscured the detection of gas puffing. In contrast, the RS acoustic sensors successfully captured gas puffing signals up to 2 km from the crater rim. This work highlights the potential of low-cost RS sensors as effective tools for volcano monitoring and underscores their value for research when combined with complementary techniques such as thermal video recordings.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

The 2021 deep volcano-tectonic swarms of Pinatubo volcano: A case of magmatic intrusion in a deep plumbing system

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Deep volcanic earthquake swarms can be caused by various geotectonic processes, ranging from external tectonic activity to inner volcano dynamics. Seismic swarms of volcano-tectonic (VT) earthquakes occurred in Pinatubo Volcano, Philippines in 2021, three decades after its cataclysmic eruption in 1991. These earthquakes originated at depths far below the assumed shallow magma reservoir. The precise location and analysis of these earthquakes play a critical role in volcano monitoring and determining the processes involved in generating these earthquakes. In this study, a minimum 1D velocity model for Pinatubo Volcano was estimated using the 2021 local VT swarms and simultaneous inversion approach, which served as the basis for precise location using double-difference method. The resulting earthquake distributions were spherical or cylindrical beneath the volcano's edifice. Cross-correlation analysis indicated that most events were non-repeating, with short-lived families of repeating events. Focal mechanisms obtained using first-motion polarity and full waveform inversion indicated primarily normal faulting with strike-slip components, although there were differences in the fault plane orientations. These results suggest that the 2021 VT swarms of Pinatubo were driven by volcanic processes originating from a deep-seated intrusion or fluid migration beneath the volcanic edifice around 35km to 40km deep. While this period of unrest did not culminate in an eruption, the resulting data will be crucial for developing a conceptual model of the magmatic system of Pinatubo. These findings also have broad implications for more accurate hazard assessments and eruption forecasts, as well as providing an analog for other volcanoes exhibiting similar earthquake characteristics.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Seismological Models and Seismicity Patterns in the Kivu Rift and Virunga Volcanic Province (D.R. Congo / Rwanda)

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The active volcanoes Nyamulagira and Nyiragongo in the Virunga Volcanic Province (Western branch of the East African Rift) threaten the city of Goma and neighbouring agglomerations. Urbanisation in the direct vicinity of the volcano undergoes sustained rapid growth, and the region counts 1 million inhabitants today. The successive eruptions of Nyiragongo which occurred in 1977, 2002 and 2021 caused major disasters and casualties. Moreover, destructive earthquakes can also affect the region. Between 2013 and 2022, the first dense real-time telemetered broadband seismic network in the Kivu Rift region (KivuSNet) was gradually deployed in the frame of several research projects and was fully operational with a sufficient station coverage (>10 stations) since October 2015. Due to the fundamental importance of monitoring the seismicity in this region, substantial efforts were made for setting up this network permanent with real-time data acquisition, which thus rapidly became the main seismic network of the Goma Volcano Observatory for daily routine monitoring work. This contribution will present the lessons learned from >6.5 years of continuous seismic monitoring in the Kivu basin, and the current status of seismological information derived from these data, including a robust 1D seismic velocity model and a calibrated local magnitude scale for the Kivu Rift region. The complete seismicity catalogue (volcanic and tectonic events) has been relocated. The main seismic patterns will be discussed with a special emphasis on how this new knowledge can help the Goma Volcano Observatory in improving its monitoring.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.1: Volcano seismology and acoustics: new approaches in monitoring, modelling and interpretation

Allocated presentation: Poster

Do the rheological properties of compliant weak rocks dominate the seismic response of the upper volcanic edifice?

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The upper volcanic edifice plays a crucial role in influencing the final stage of the magma migration pathway to the Earth's surface. It is commonly expected that this migration will produce a distinct seismic response, which can be tracked through the shallow subsurface. As a result, shallow Long Period (LP) seismicity and volcanic tremor capture lots of interest of the scientific community, related to hazard assessments. However, a detailed analysis of LP and tremor signals reveals that these types of events can be generated in ways that do not necessarily involve migrating fluids. Additionally, it has long been recognized that a brief period of quiescence often precedes eruptions, which remains puzzling if seismicity-related fluids are nearing the surface. In this study, we examine the role of compliant and weak rocks, which are typical in upper volcanic settings, on the seismic response and seismicity generation. We demonstrate that many of the observed characteristics of pre-eruptive seismicity can be explained by considering the rheology of the upper edifice. This analysis also highlights the presence of exceptionally weak structures at the scale of the entire edifice.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Talk [Invited]

Creation and analysis of a multi-hazard database for the island of Tenerife (Canary Islands).

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In the context of escalating climate change impacts and heightened frequency of natural disasters, the imperative for robust multi-hazard assessment and proactive mitigation strategies has become evident. Tenerife (Canary Islands), situated in the Atlantic archipelago, encapsulates the challenges faced by communities globally, prompting a paradigm shift towards anticipatory disaster management. This study presents a pioneering effort to establish a multi-hazard database for regions impacted by multiple natural hazards, using Tenerife as a case study, to provide a foundation for accurate risk assessments and decision-making. Our methodology involved collection and analysis of 500 years of historical data on volcanic activity, earthquakes, floods, landslides, and extreme weather events, allowing us to identify patterns, vulnerabilities, and resilience measures. Our approach aims to empower stakeholders with a nuanced understanding of natural processes. The database reveals patterns in hazard occurrence and impacts, such as frequent floods linked to heavy rainfall and ravine overflows. It also highlights increasing frequency and severity of these events in recent decades. Other hazards, like rockfalls and landslides, pose risks in areas affected by human activities. Key recommendations include ravine cleaning, water retention areas, reforestation, enhanced geotechnical studies, and slope stabilization efforts to mitigate landslide risks. This approach is applicable to Tenerife but serves as a model for other regions facing multi-hazard scenarios. By leveraging historical insights alongside contemporary methodologies, this contribution aims to strengthen resilience and inform mitigation strategies. This contribution has been partially funded by the research grants MAPCAN (CSIC Intramural Especial 202130E083) and VOLCAN (EC ECHO 101193100).

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Talk [Invited]

Reconstructing the most explosive volcanic eruption this century

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The 2022 eruption of the shallow submarine Hunga Volcano, Kingdom of Tonga, was the most explosive volcanic eruption this century and the first VEI >5 eruption in the satellite era. The eruption generated a devastating tsunami with >20m run-up, and damaged subsea telecommunications cables disconnecting Tonga from the global internet, with many Tongans cut off for more than a year. The eruption sequence and associated subaerial and seafloor change are unusually well constrained, from a combination of pre-eruption remote sensing, seafloor surveys and sampling, fast-response post-eruption seafloor surveys and sediment coring that characterised offshore eruption deposits, land-based surveys of tsunami deposits and damage, and personal testimonies. These collectively provide a unique opportunity to study the deposits and record of volcanic hazards above and below the ocean surface. These data reveal the creation of fast-moving (up to 120 km/hr) submarine volcaniclastic density currents, produced as the eruption column collapsed onto the steep submerged slopes of the volcano, travelling distances > 100 km, depositing up to 40 m of material, and damaging telecommunications cables. Submarine deposits evidence complex flow in all directions. Onshore observations reveal multiple tsunami waves, and evidence of an older tsunami, with the resultant deposits and preservation being strongly controlled by local topography and offshore sediment availability. This eruption provides a rare opportunity to link observed volcanic processes unequivocally to the deposits they produced and provides valuable observations that can aid hazard forecasting and inform interpretation of similar deposits elsewhere and further back in the geological record.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Talk

Feedbacks between structural development, eruption style and output rates at Anak Krakatau, Indonesia

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Edifice destabilisation is a common volcanic process and although relatively infrequent, large-scale gravitational collapses can occur across all volcano-tectonic settings. Growing evidence suggests that cycles of edifice growth and destruction, through variable loading of the underlying magma reservoir, influence magma storage conditions and eruptive behaviour on a range of timescales. However, difficulties developing high-resolution reconstructions of activity surrounding volcanic collapse limit our understanding of these relationships. In December 2018, Anak Krakatau underwent a major structural failure of its south-western flank. Unlike most historical lateral collapses, this failure occurred just 91 years after the volcano emerged above sea-level in 1927. As a result, Anak Krakatau offers a uniquely well-documented record of a complete cycle of edifice construction, failure and subsequent regrowth. This work exploits this high-resolution documentation, using remote sensing techniques to generate a time series of 3D island reconstructions to analyse Anak Krakatau's volumetric output at 34 points. Results indicate a two-stage output cycle before the 2018 collapse, differentiated by an abrupt decrease in output rate coinciding with both a shift in eruptive style and increase in vent height. Following collapse, Anak Krakatau entered a new accelerated regrowth phase, with 4-years of rapid volumetric increase equivalent to 62-years of historical growth (1950-2012). By employing additional petrographic studies of tephra from five key stages through this cycle, we further investigate this coupled relationship between structural development, magma storage conditions and output rates. This is important in understanding edifice collapse at other volcanoes globally and constraining future stability at Anak Krakatau itself.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Talk

The Sea-Bottom Benchmark system in Aira Caldera and its current performance

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The Sea-Bottom Benchmark system (SBB) was installed in 2.2 kilometers northeast off Sakurajima on March 2023. SBB comprises an anchor of 19 tons weight and a universal coupled buoy of 40 meters length and 21 tons weight. The measuring system comprises four GNSS antennas, two GNSS receivers, a mobile router. The power supply system includes three iron phosphate lithium-ion batteries, three photo-voltaic cells, and a charge controller. Three of the antennas are placed at the end of 1 meter beams and form the apex of a right triangle. Data in the receivers are pulled up once a day through a LTE commercial network, and are processed in the machine in the headquarters automatically. The position at the top of the anchor is calculated through the attitude reduction with using a GNSS antenna array at the top of the buoy, which represents ground deformation at the seabed. The reduced location result show a simple normal distribution with the standard deviations of location 0.17 m for lateral components and 0.017 m for the vertical component. The system operation has been running successfully for almost two years after the establishment without any day-long break and stood through strong wind of typhoon storms. Although almost flat trend are observed in the surrounding station, the result from SBB shows on-going local subsidence at one year after the installation. The reduction of the local subsidence is necessary to resolve exact ground deformation. The reduction will be performed through continuing operation of SBB.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Talk

Tsunamis generated by eruptive column collapse: an experimental approach

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During shallow underwater or island volcanic explosive eruptions, rising plumes composed of gas and suspended magma fragments can reach altitudes up to 40–50 km (e.g., Krakatau 1883, Hunga Tonga–Hunga Ha'apai 2022). When the eruptive column collapses, the granular material falling into the water at high velocity becomes a potential tsunami source. To investigate this poorly-documented mechanism of tsunami generation, we conducted laboratory experiments by releasing monodisperse glass beads (66±10 µm in diameter) vertically from a hopper into a 7 m-long water-filled channel. We tested a range of water depths of 20-25 cm and fall heights of 65-115 cm, using particle mass of 2-35 kg. We recorded wave dynamics using shadowgraphy with LED panels and two high-speed cameras (250 fps), and quantified through image analysis the leading wave amplitude (up to 5 cm), speed (1.3 - 1.6 m/s), and wavelength (1.5 - 4.5 m). We also identified three successive wave types: rim waves, collapse waves, and uplift waves. Our results show that initial wave speed and amplitude at 1.4 m from the impact zone increase with particle mass, flow rate, and volume fraction, and reach a maximum value determined by the limited water depth before it decreases. The wave behavior corresponds to an intermediate-depth regime, differing from the shallow water assumption. Our results demonstrate that eruptive column collapse into water can generate tsunamis. This issue needs to be further investigated in the context of volcanic hazards.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Talk

Holocene eruptive histories of New Zealand's nearshore volcanoes: Insights from marine cores around Tūhua and Whakaari volcanoes

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New Zealand (NZ) hosts two recently active near-shore island volcanoes in the Bay of Plenty: peralkaline rhyolite Tūhua (Mayor Island) and andesitic Whakaari (White Island). Both show evidence for explosive activity that may have impacted mainland NZ. Whakaari's eruptive history (<3 ka) is only partially understood, and it remains unknown whether the volcano produced large explosive eruptions. Tūhua's geology was studied extensively but the extent and ages of recent (<7.2 ka) explosive activity remain uncertain. Our study investigates the explosive eruptive histories of these volcanoes by examining marine piston cores from proximal and medial sites to refine the numbers, ages, sizes, componentry, and compositions of eruptions. Preliminary observations identify larger, infrequent eruptions from Tūhua, and smaller, but more frequent events from Whakaari. Mainland rhyolitic tephras from the mainland Taupō Volcanic Zone, including the 1314 AD Kaharoa, 232 AD Taupō and 8 ka Mamaku events, have been identified, providing good age constraints. Cores around Tūhua reveal at least two explosive peralkaline events younger than the ~7.2 ka caldera-forming eruption. A bimodal unit within several Whakaari cores confirms that the volcano erupted just before or simultaneously with the Kaharoa eruption. Coarse-grained, poorly sorted, shell-rich tephra units in proximal Whakaari cores indicate mass flow activity. Radiocarbon dating of bracketing sediments will determine whether these deposits represent one or multiple events, to assess tsunami generation potential. Results from ongoing analyses and initial age-depth models will be discussed and compared to onshore observations and existing tephra records to revise volcanic hazard assessments for mainland NZ.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Talk

Insights from the first two Years of the SANTORY shallow Seafloor Observatory: Advancing submarine volcanic monitoring in the Aegean Sea (Greece)

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SANTORY is a state-of-the-art project aiming at submarine volcanic hazard monitoring in the Aegean Sea. Focused on Kolumbo submarine volcano NE of Santorini Island, this cutting-edge observatory combines advanced imaging, physical and chemical measurements, and real-time monitoring technologies to address one of the region's most significant volcanic threats. Over the past two years, SANTORY has provided unprecedented insights into Kolumbo's geological dynamics and volcanic activity. High-resolution 3D mapping revealed steep slopes, mass-wasting deposits, and hydrothermal vent fields, critical for assessing seafloor instability and potential eruption risks. Novel hyperspectral imaging and autonomous video systems have captured vent activity, bubbling plumes, and environmental changes, providing the most complete assessment of hydrothermal processes to date, and establishing a baseline for potential tracking of underlying volcanic processes. Autonomous sensors deployed on the crater floor have been monitoring hydrothermal outflow temperature, pressure, and chemistry of fluids; these parameters will help quantify chemical fluxes, and reveal periodic variations driven by tides, in addition to magmatic activity. Datasets revealing these hydrothermal fluctuations may thus be critical in detecting precursors signals of volcanic unrest.

Chemical and isotopic analyses confirmed the degassing of CO_2-rich hydrothermal fluids with a mantle-like $^3He/^4He$ signature, reinforcing Kolumbo's potential for hazardous eruptions. SANTORY constitues an initiative for developing a protocol for volcanic hazard mitigation that can be extrapolated to other systems. By integrating cutting-edge technologies and multidisciplinary expertise, the project delivers actionable insights to improve early warning systems and protect vulnerable coastal communities. SANTORY sets a new benchmark in safeguarding against submarine volcanic threats.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Talk

New evidence for sector collapse preceding the devastating 1883 Krakatau eruption

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The 1883 eruption of Krakatau remains the most catastrophic volcanic eruption in recorded history. It generated tsunami wave runup up to 40 meters high, followed by pyroclastic density currents impacting coastlines hundreds of kilometers away. Current understanding suggests that the violent climactic eruption was initiated by overpressure in the magma system and that the pyroclastic flows generated the main tsunami. New marine geophysical and geochemical data from the west of Krakatau provide evidence for a large debris avalanche deposit containing blocks up to 300 m long and wide. Seismic data and geochemical fingerprinting of tephras indicate that the debris avalanche occurred prior to the ejection of most of the eruptive material. Given the size, distribution, and distance of these blocks, the avalanche must have resulted from a high-energy event, such as sector failure. We therefore propose that the primary trigger for the large explosive eruption was a sector collapse of Krakatau, and this mechanism contributed to tsunami generation. This interpretation is consistent with previous observations, such as that the surge component of the pyroclastic density currents was directed northward to westward. Large scale mass movement and lateral failure, generating landslides, may be an under-recognised process occurring as part of caldera subsidence. Causal links between sector collapse and the triggering of catastrophic eruptions have been observed elsewhere, including Mt. St. Helens in 1980. Our results further suggest that sector collapse may be an important trigger for large explosive eruptions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Geomagnetic Signatures of the Hunga Tonga Volcanic Eruption

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CSIR National Geophysical Research Institute The Hunga-Tonga volcano eruption released a tremendous amount of mass and energy into the atmosphere on January 15, 2022. The related lightning strikes disrupt the worldwide electric circuit. In this study, we have mapped the (i) global geomagnetic disturbances caused by AGW generated by the volcanic eruption, (ii) Schumann Resonance parameters derived from modulations of ELF observations caused by the intense lightning phenomena that accompanied the volcanic eruption. Our analysis shows that (i) registration timing of geomagnetic disturbance at each observatory indicates the different modes of propagation between 180-350 m/s, indicating low-frequency Acousto Gravity Wave components causing ionospheric perturbations, (ii) noticeable changes in Schumann Resonance (SR) frequency modes (7 to 21 Hz) occurred in the total power linked to heightened lightning activity, (iii) velocities are found to be similar at similar distances in the northern and southern hemispheres from Hunga-Tonga, (iv) time difference between the SR and geomagnetic disturbance signature at observatories is found to be increasing with increase in distance from the eruption, (v) fluctuations in VTEC at the Indian and Russian sectors show that the geomagnetic disturbances are linked to. These observations linking a localised lithospheric phenomenon to ionospheric disturbances over 16000 km, spread over nearly 24 hours indicate a high degree of coupling between lithospheric and ionospheric processes. Additional geophysical data at different distances from Tonga, will provide crucial information on how atmospheric and ionospheric winds were impacted by the eruption, which in turn modified the geomagnetic field.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Investigating Volcanic Hazard on Flores Island, Azores

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Volcanic hazard assessment studies are critical to ensure the awareness and safety of those living in the vicinity of these natural phenomena. Flores is a small oceanic island with active volcanism located in the Azores Archipelago, home to approximately 4,000 inhabitants living in small and sometimes isolated settlements. However, to date, no evaluation of its volcanic hazard has been carried out. This research aims to fill this gap by exploring volcanic hazard on the island for the first time, through characterizing recent volcanic events and their sources, determining eruption source parameters, simulating the dispersal of volcanic products and identifying areas likely to be affected. To achieve this, we built upon recent studies of the latest volcanic events to extract eruption source parameters and then used the VORIS (Volcanic Risk Information System) GIS-based software to simulate different eruption scenarios and perform a consequent volcanic hazard analysis. Results found that volcanic hazard varies between settlements, depending on the surrounding topography, the proximity to the two volcanic systems (Comprida and Funda), and the volcanic products they are affected by. The most vulnerable settlements are Santa Cruz das Flores and Lajes das Flores, which are also the most populated. Critically, this work addresses the lack of volcanic hazard assessment for Flores Island, by providing a simple guide to the inhabitants with regards to their level of volcanic hazard and offering the civil protection authorities basic recommendations.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Tsunamis and pyroclastic flows over water during the 1815 eruption of Tambora

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The physical processes leading to tsunami during a volcanic eruption are often poorly documented and poorly constrained, thus seriously complicating hazard assesment and the implementation of early warning strategies. These difficulties apply in particular to major explosive eruptions, during which the sources of tsunami are multiple (underwater explosions, rapid ground subsidence, eruptive column collapse, pyroclastic density currents, and atmospheric waves). Among all these mechanisms, the generation of tsunamis by pyroclastic density currents involves complex physical processes that can be understood on a laboratory scale (channel experiments). But the lessons learned from these experiments need to be correlated with field data on natural events. We here take the example of the Tambora eruption in 1815 as a case study, with the aim of identifying tsunami deposits in the coastal stratigraphy of the Saleh Bay, 40-50 km West of the volcano. The volcano-sedimentary sequences studied provide information on the chronology of events (tephra falls, pyroclastic flows, tsunamis) and thus place constraints on the magnitude and source of tsunamis in the framework of the different stages of the eruption. We also document the propagation of pyroclastic flows over 20 km of water in the bay. These field data are then compared with empirical laws derived from experimental work, enabling tsunami wave heights to be related to pyroclastic flow parameters (flow density, front height, front velocity, mass flux) at the impact with water.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Erosion controls direction of lava dome growing – case study of the 2022-2024 island forming eruption at Home Reef (Tonga) analyzed from space

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The submarine volcano Home Reef is part of the Tonga Volcanic Arc, one of the most active volcanic arcs on Earth. On September 9, 2022 the Normalized Hotspot Indices (NHI) system, performing operationally at global scale, automatically notified the presence of a thermal anomaly at Home Reef Volcano from Sentinel-2 data. Starting from this information, we integrated multi-sensor/multi-platform satellite datasets, including very high spatial resolution multispectral data of PlanetScope and radar data of TerraSAR-X, as well as infrared data from Sentinel-2, Landsat-8/9, MODIS and VIIRS, to monitor and characterize the youngest eruption at the Home Reef Volcano over a two-years period. Based on this multi-sensor approach, we investigated the eruption dynamics (e.g., in terms of thermal activity and relative intensity level) and studied the lava dome growing and erosion processes. The island forming eruption showed four distinct phases: First, lava dome growing formed an approx. 54,900 m^2 large circular shaped island during September to October 2022. In the following, further dome growing phases towards the south (September–November 2023) and east (January 2024 and June–September 2024) extended the island to over 122,000 m^2. We show that erosion processes control the location of the new vent, which is then active in the next phase, and therefore predetermine the growing direction of the next phase lava dome. The latter might be crucial for the location of a potential tsunami-genic landslide-like dome collapse.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Predicting tsunamis generated by pyroclastic flows near the source: Application to the 2019-2021 paroxysms at Stromboli, Italy

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When volcanic explosive eruptions occur near the coastline, pyroclastic density currents may reach the sea and generate tsunamis (e.g., 1883 Karakatau, 1997-2003 Montserrat, 1994 Rabaul), increasing areas vulnerable to volcanic hazards. One of the major challenges is to be able to predict the amplitude of tsunamis close to the source. Due to their hazardousness, intermittency, and complexity, a better understanding of tsunamis requires laboratory experiments, theoretical description and numerical modelling. To this end, we investigate experimentally the entrance of pyroclastic flows into the sea, and consequently generated tsunamis, by considering fluidized granular flows that propagate along an inclined plane, and then enter a pool of water. By quantifying the flow parameters and wave properties, we reveal that mass flow rate and volume are the main contributing parameters in the wave generation process. By combining all flow conditions in a single dimensionless parameter, we provide an empirical prediction of the amplitude of the leading and largest wave near the source, which matches experimental data. Finally, we compare our empirical prediction with recent and unique field data recorded during the 2019-2021 paroxysms, at Stromboli (Italy), which encourages us to extend this comparison to other field data in order to assess its reliability and limitations.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Insights from direct shear experiments into the stability of thrust sheets buttressing the submarine flank of Kilauea volcano (Hawaii, USA)

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The south flank of Kilauea volcano (Hawaii, USA) is mobile and is sliding seaward along a basal décollement at rates of at least ~10 cm/yr. The slip is accompanied by earthquakes and landslides. The Hilina Slump rides on top of the mobile flank but it has not yet failed catastrophically as is observed elsewhere on the islands. It is suggested that stacked thrust sheets at the toe of the submarine flank buttress and thereby stabilize the active slump. The mechanical properties of the slump and thrust sheets are poorly known, but could play a role in their deformation behaviors and stability of Kilauea's mobile flank. We performed direct shear experiments on samples collected from submarine exposures of the thrust sheets and the Hilina Slump to better understand the mechanical behavior of these two systems. Our results show that both velocity-weakening and velocity-strengthening frictional behavior are observed for the tested samples. The observed friction velocity dependence depends on the sliding velocity, with velocity-strengthening behavior occurring predominantly at low velocities. Intact samples are stronger and show more velocity-strengthening behavior, compared to powdered rocks which are weaker and show more velocity-weakening behavior. The powdered material is representative of pre-existing fault zones and thus, we can expect potentially unstable sliding behavior for the thrust sheets. Moreover, stick-slip behavior is observed for altered surface sediments of the Hilina Slump. Thus, material behavior across the submarine flank is very variable which might explain the occurrence of different types of deformation structures and slip behaviors at Kilauea.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Cape Riva versus Minoan eruption: reassessing the magnitude of caldera-forming eruptions at Santorini

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Although caldera-forming eruptions are among the most catastrophic natural hazards, an accurate quantification of the volume of ejected material and their magnitude remains a challenge. Santorini in the Aegean Sea is one of the world's most prominent calderas and the result of at least five caldera-forming eruptions. The 1600 BCE Minoan eruption represents the most recent caldera-forming event, and is among the most extensively studied eruptions worldwide. While recent marine geological and geophysical analyses enabled reconstruction of its volume and temporal evolution in greater detail, little is known about its predecessor, the caldera-forming Cape Riva eruption, which occurred ~22 ka. New analyses of marine sediment cores suggest that the Cape Riva eruption produced a tephra volume comparable to or exceeding that of the Minoan eruption. Here, for the first time, we integrate high-resolution 2D and 3D seismic reflection data with sedimentological constraints from marine sediment cores to assess the volume of the Cape Riva eruption with high precision, and compare it to the Minoan eruption. Our results indicate that the Cape Riva eruption deposited, at least locally, a significantly thicker offshore ignimbrite layer than did the Minoan eruption. This suggests that the volume of the Cape Riva eruption might have exceeded that of the Minoan eruption, and that previous estimates of the offshore ignimbrite for the Minoan eruption might have been overestimated. Our study highlights the complexity of evaluating large-scale eruption products in the marine environment, and underscores the importance of integrating high-resolution seismic imaging with marine sedimentological analyses.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Using rapid probabilistic flow modelling to support hazard assessment during unrest crises at data-poor volcanic islands

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Populated volcanic islands present major challenges to hazard assessment and risk management when the volcano enters a period of unrest. Their small size means settlements are often located close to the crater and within potential hazard footprints. Volcanoes with longer quiescence pose further complexity due to scarcer knowledge of prior eruptive hazards or impacts. Sangihe Besar is a volcanic island in Indonesia whose volcano, Gunung Awu, has a history of phreatic and phreatomagmatic eruptions that have caused fatalities from volcanic flow and tsunami hazards. Awu recently entered a new period of unrest, reigniting concerns about potentially hazardous eruptive scenarios. Modelling scenarios can constrain the spatial range and intensity of associated hazards, which may subsequently inform risk reduction actions for Awu's population. However, the complexity of Awu's previous fatal eruptions (dome-lake interaction with latency) and paucity of stratigraphic data from previous eruptions complicates this undertaking. We deal with large epistemic uncertainty through an 'impacts-focused' approach, modelling column-collapse pyroclastic flows across a broad parameter space to identify the minimum eruption source parameters (ESPs) that could generate sectoral impacts. These ESPs may be linked to potential eruptive scenarios that could evolve in a future crisis. We explore how model outputs may complement existing hazard maps and overlay available exposure datasets to evaluate potential inundation of populated areas. This work demonstrates the utility of open-source models to rapidly provide preliminary probabilistic hazard assessments at data-poor volcanic islands newly in unrest.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

MEDUSA: a Multidisciplinary Marine Infrastructure for the Permanent Monitoring of the Campi Flegrei Volcanic Area (Italy)

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In the marine portion of the Campi Flegrei caldera (Italy), a permanent and multidisciplinary marine monitoring infrastructure (MEDUSA) has been operational since 2016 providing the extension of the on-land monitoring networks. With the continuous production of multi-parametric data, MEDUSA contributing to a more precise definition and comprehension of the deformation pattern exhibited by the submerged portion of the Campi Flegrei volcanic area, in a shallow water environment. MEDUSA is comprised of four systems, each of which is composed of a geodetic buoy (MPP, Multi-Parametric Platform) and an SSO (Seafloor Scientific Observatory) connected to its buoy by an electromechanical subsea cable, which provides power, data communication and GPS timing. The systems are located at about 2.5 km from the coastline and at a depth ranging from 40 to 100 m. Each MPP is powered by an autonomous photovoltaic system and is equipped with geodetic and environmental sensors, as well as a GSM-based communication system. Each SSO is equipped with a variety of geophysical, geodetic, and oceanographic sensors. A number of these sensors are fixed on the SSO frame, while others are installed in a titanium subsea housing–mounted within the frame–and connected to a multi-channel data acquisition system. More than 200 data channels, spanning a frequency range from 1 to 200 Hz, are collected, time-tagged with GPS-UTC time sync, and transmitted in real-time to the on-land center for visualisation and analysis in the monitoring room. Data is stored locally in databases for post-processing analysis and accessible on a website.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Proposal of a combined generalized rainfall threshold for landslide occurrence on São Miguel volcanic island (Azores, Portugal)

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Rainfall-triggered landslides pose a significant threat to infrastructures and human lives. Defining accurate rainfall thresholds is crucial for anticipating landslide events and implementing effective early warning systems. This study, focused on São Miguel volcanic island (Azores, Portugal), aims to propose a generalized rainfall threshold, combining preparatory and trigger thresholds, based on data obtained from four different locations on the island. A total of 62 landslide events, along with rainfall data from 1977 to 2020, were analysed. The Generalized Extreme Value (GEV) distribution, with parameters estimated via Maximum Likelihood Estimation (MLE), was used to identify the cumulative rainfall-duration (R_{cum}-D) pair with the highest return period for each landslide event, forming the preparatory threshold. The triggering threshold was based on the rainfall intensity recorded on the event day (I_{D1}), but it also depends on the duration of the preparatory rainfall period. The combined threshold anticipates landslide events when both thresholds are exceeded. The generalized combined threshold for São Miguel Island was obtained through logarithmic transformation of the normalised thresholds by the Mean Annual Precipitation (MAP) of each rainfall station. Linear regression was used to determine the parameters *a* and *b* of the generalized combined threshold. High MAP areas, such as Furnas and Sete Cidades, have thresholds where the rainfall required to trigger landslides is less demanding. In contrast, regions with a lower MAP, such as Ponta Delgada and Santana, have more demanding, reflecting their lower rainfall regimes. The normalized functions of the generalized combined threshold for the island are $R_{cum}=0.034D^{-0.34}$ and $I_{D1}=0.034D^{-0.17}$.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Evidence of mass-wasting and large flank-collapse at Fogo, Cape Verde: New insights from marine geophysical data

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Gravitational instabilities are recurrent processes affecting volcanic islands during their lifetime. Flank collapses, as a result of instability, can trigger secondary failures and tsunamis that may cause damage to coastal and offshore infrastructure. A complex history of mass-wasting events has been described in the Cape Verde Archipelago using marine geophysical datasets, including the ca. 73 ka Monte Amarelo flank collapse at Fogo which triggered a mega-tsunami. To better understand the emplacement of the submarine Monte Amarelo debris avalanche deposits and the interplay between landslides, intrusions and volcanism, we investigated high-resolution multichannel seismic (MCS) reflection data gathered in 2019 during the research cruise M155 onboard R/V METEOR. The internal architecture of the Monte Amarelo deposits as captured by the MCS data, in combination with high-resolution bathymetric data, allows precise estimates of their volume and extent and helps us to decipher its emplacement and impact on pre-existing sediments. MCS data covering Fogo's southern volcaniclastic apron show multiple mass-wasting events coinciding with volcanic intrusions and associated faulting. These deposits are predominantly located above high-amplitude reflector packages, which we interpret to represent increased input of volcaniclastic material. In combination with ongoing work on sediment cores, we aim to establish a chronological timeframe of landslide processes in the Cape Verde Archipelago and estimate recurrence periods. Our results contribute to the understanding of flank collapse and mass-wasting at volcanic islands, and their relation to tectonic and volcanic activity, along with improving hazard assessments and monitoring at unstable volcanoes.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Modeling Deformation at Marine Volcanoes: Interpretation and Monitoring Implications

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Marine volcanoes exhibit significant topographic variations, extending from deep underwater to high above sea level. Their submerged flanks create complex, asymmetric topographies that are often simplified as flat surfaces in deformation models, potentially leading to inaccurate assessments of deformation sources and hazards. Our study investigates the impact of complete marine volcano topography on deformation modeling by applying geomorphometric parameterization to quantify asymmetry and steepness. Building upon an existing analytical solution for triangular dislocations, we incorporate the full volcano structure—from its submarine base to its subaerial peak—and discretized, complex source geometries within a full-space modeling domain. Results show that models including complex topography differ significantly from flat-surface approximations, underestimating displacement magnitudes by at least 20–35% and misrepresenting their spatial distribution. Geomorphometric parameters provide a first-order estimate of these deviations. For island volcanoes, displacement fields are not limited to the landmass but extend into the submarine edifice, highlighting the importance of accounting for underwater topography as submarine monitoring technology advances. This approach enhances the understanding of volcanic deformation processes and offers tools to improve GNSS network design, ensuring more accurate monitoring and assessment of volcanic hazards.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Sensitivity analysis of source parameters for gravitational mass-flow generated tsunamis at Stromboli

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Tsunamis generated by granular flows represent significant hazards to coastal communities, particularly near volcanic islands with steep slopes and persistent activity. Stromboli volcano exemplifies this, with recurrent gravitational activity causing tsunamis over the past century. Here, we investigate the sensitivity of tsunami generation and propagation to key gravitational mass-flow parameters using the Multilayer-HySEA model. We explore variations in granular flow initial position (subaerial versus submarine), volume, density, friction angles, and water-landslide coupling. Results indicate distinct behaviors based on flow position for volumes from 3 to 30 × 10^6 m^3. Submarine flows show a linear relationship between volume and maximum sea surface elevation, with the slope of the fit predicting 0.3 ± 0.3 m per 10^6 m^3 near Stromboli village. Subaerial flows show a logarithmic trend, with maximum elevations per 10^6 m^3 decreasing as volume increases, with typical values of 0.7 ± 0.7 m per 10^6 m^3 near the village. Sobol's analysis shows that initial flow position drives variability in maximum elevation (~60%), followed by volume (~20%) and friction angles (~10%). Separating subaerial and submarine cases reveals differences and localized trends. Tsunamis generated by subaerial flows are primarily influenced by volume (~60%), whereas submarine flows show balanced sensitivity between volume (~37%) and position (~35%). In both scenarios, friction angles and water-landslide coupling contribute to variability, although to a lesser extent. Our study supports prior findings at Stromboli and provides insights for reconstructing tsunami source parameters from sea-level measurements, enabling rapid impact forecasting for the island.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

A "Land to Sea" global morphometric database of volcanic islands

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Volcanic islands, marine and coastal volcanos pose the potential threat of volcanogenic tsunamis through explosive eruptions or mass wasting events. These are difficult to predict and grant little reaction time, while affecting coastal communities beyond the immediate proximity of the volcano. It is therefore important to find factors contributing to volcanic flank collapse before the event occurs and thus identify potentially hazardous volcanos. However, only a maximum of 10% of the volume of any volcanic island is exposed above sea level and can thus be monitored directly by satellites. While some volcanic islands have been studied extensively both on- and offshore, low-resolution (~500 m) bathymetric DEMs based on satellite altimetry are often the only available information about the seafloor morphology in less well studied areas. Here, we generate and analyse a global morphometric database of 200 volcanic islands selected from the Quaternary volcanic database of the Global Volcanism Program (GVP). The morphology is characterised by more than 20 parameters defining size, shape and asymmetry, in order to quantify correlations between the geomorphology and potential for tsunamigenic mass wasting events. For our analysis, we use the composite bathymetric DEM of the General Bathymetric Chart of the Oceans (GEBCO) below and TANDEM-X 30m EGM above sea level, and the newly developed VolcPackage software for the edifice delineation and extraction of morphometric parameters. Our results will help to better understand morphological control on volcanic instability. Additionally, the database will be freely available and can be used for a variety of future research questions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Semi-automated volcano monitoring using distributed MOLA seafloor sensor networks

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Marine volcanic eruptions, landslides and associated tsunamis pose a significant threat to coastal communities and seabed infrastructure. While most volcanic eruptions and landslides are preceded by precursory processes that provide effective early warning for terrestrial volcanoes, no dedicated tools and approaches exist for the vast majority of submarine volcanoes. Recent advances in embedded and distributed machine learning, and the availability of low-cost underwater communications technology, allow for the development of intelligent sensor platforms, such as the compact MOLA seafloor lander system[HK1] . The MOLA prototype can be equipped with a variety of sensors, including seismometers, hydrophones, inclinometers, accelerometers, pressure gauges, thermometers, cameras and chemical sensors, and consists of a multi-channel data recorder, an underwater acoustic communication device (ahoi modem) and a central analysis and computation unit. Multiple MOLA landers can form seafloor sensor networks that perform embedded and distributed data analysis, such as earthquake detection and localisation, or acoustic quantification of flow rates from hydrothermal vents. The network shares data and analysis results via acoustic communication, while on-node data analysis and event detection using thresholding or neural network-based data filtering significantly reduces data transfer requirements and enables (semi-)autonomous system assessments. These could, for example, indicate increased eruption probability or evidence of slope deformation, and could be uploaded to central observation facilities or early warning systems with little delay via gateway communication nodes at the sea surface. The MOLA system has already been tested offshore Etna, in the Santorini caldera and on Kolumbo volcano.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

The Sumatra Fault and Krakatau: How Regional Extension Shapes Volcanism in the Sunda Strait

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The contrasting subduction dynamics along the Indonesian subduction arc—perpendicular beneath Java and oblique beneath Sumatra—have resulted in the formation of a NW-moving sliver plate offshore Sumatra. The strike-slip motion ceases as the Sumatra Fault bends southward in the Sunda Strait, which hosts the highly active Krakatau volcano, leading to extension and the formation of the Semangko pull-apart basin. Krakatau, which was destroyed by a violent eruption in 1883, and its successor Anak Krakatau are prone to flank instability and are more southerly than volcanoes on Sumatra or Java. While both observations have been attributed to the regional extensional regime in the Sunda Strait having a significant influence on the evolution of Krakatau, the distribution of fault systems around and beneath Krakatau has remained poorly constrained. We integrate high-resolution 2D multichannel seismic data from the 2023 research cruise SO299-2 with an extensive high-resolution sparker seismic dataset acquired around the Krakatau Archipelago in 2018 and 2023 (UKGrant_Ref:NE/S003509/1) to investigate the tectonic controls on volcanism in this region. Our analysis identifies predominantly NW-SW to NNW-SSE striking normal faults, associated with the regional extension in the Sunda Strait. We interpret a major NW-SE striking, SW-dipping normal fault in the northwest of the study area as the north-eastern extension of the Sumatra Fault, which bends southward to form the eastern boundary fault of the Krakatau Graben, a mostly filled graben adjacent to the Semangko pull-apart basin. Krakatau lies on the flank of the horst which probably contributes to its instability and eruptive behaviour.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Developing a compact and mobile observation package for real-time monitoring in a remote island: application in Gaua island, Vanuatu

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Installing a permanent monitoring network is difficult in some volcanoes, especially those in remote islands. The lack of monitoring capability would prevent scientists and authorities from rapidly and accurately evaluating volcanic activity and transferring information to the public during a crisis. It also increases the risk of working at the volcanoes. To improve these situations, we are developing a quasi-real-time seismic observation package that is easy to install. The package consists of commercially available instruments: a digitizer (Minimus+, Güralp), a short-period seismometer, a mobile router, and LIPO batteries. We can access the data stored in the SD card on the digitizer through the Güralp server using “Güralp Discovery” software from everywhere. We implemented the quasi-real-time monitoring system with a Python script, which automatically downloads the data via HTTP and uploads seismograph drums to a website for monitoring. We installed the package in one and a half hours of onsite work in Gaua Island, Vanuatu, and tested it for October 5–9, 2024, when a geological survey was conducted. No other monitoring stations had been working there. The system used the Digicel line and was operated from Port Vila, Vanuatu, and Tokyo, Japan. The monitoring website was also accessible from the survey team in Gaua. Although we lost the data flow on the second day, we kept monitoring the digitizer’s condition remotely, from which we infer that the malfunction was due to overheating. The seismic time series data were successfully recorded on the SD card throughout the experiment.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

A full view of the 15 January 2022 Hunga Tonga-Hunga Ha'apai eruption captured by distant seismic records and satellite images

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The massive eruption of the Hunga Tonga-Hunga Ha'apai (HTHH) volcano on January 15, 2022, generated global signals, which many previous studies have focused on. This study aims to retrieve the full sequence of the eruption, including precursors and smaller sub-events, which are covered by the thick umbrella cloud formed by the main eruption. We analyzed seismic records from stations near the HTHH volcano (FUTU: 752 km, MSVF: 758 km, RAR: 1627 km) and infrared imagery from the Himawari-8 satellite to gain a more detailed understanding of the eruption sequence.   We found a Rayleigh wave from the HTHH around 03:45 (UTC), about 15 min before the eruption onset shortly after 04:00. No apparent surface activity was observed. We regarded it as a precursor of the eruption. The biggest sub-event (around 08:30) following the eruptive phase (04:00 – 06:10) has already been reported in the literature based on infrasound, lightning, and satellite-based plume heights. We showed that continuous seismic tremor beneath the HTHH volcano has started to grow 50 min before the event (around 07:20). Our satellite image analyses visually confirmed that the subevent eruption began around 07:50 and was accompanied by several explosions. We also found two smaller eruptions around 13:40 and 21:50 below the semi-transparent umbrella cloud remaining at the tropopause.   We emphasize that careful analyses of data from seismic stations about 1000 km away and satellite imagery allow us to identify smaller-scale events in much more detail than one might have expected.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Monitoring of sulfur dioxide flux during the recent eruptions at Fukutoku-Oka-no-Ba and Nishinoshima volcanoes, Japan

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Monitoring volcanic activities at remote underwater volcanoes or volcanic islands is still challenging. We have applied an analysis of sulfur dioxide (SO_2) flux using a satellite sensor to monitor recent eruptions at Fukutoku-Oka-no-Ba (FOB) and Nishinoshima volcanoes, Izu–Bonin arc. We used data from the Tropospheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5 Precursor. We estimated an SO_2 flux for these volcanoes based on a daily snapshot of the spatial distribution of SO_2 column amounts taken by TROPOMI and wind speed from the weather model provided by the Japan Meteorological Agency. For the August 2021 eruption of FOB volcano, SO_2 flux during the first sustained plume phase was more than 10,000 t d^{-1} and up to 75,000 t d^{-1}. In the later Surtseyan explosion phase, SO_2 flux decreased to less than 1,000 t d^{-1} and was sometimes below the detection limit (100 t d^{-1}). For Nishinoshima volcano from August 2021 to December 2022, the daily SO_2 flux during the non-eruptive period was 100–1,000 t d^{-1}, often below the detection limit. The daily SO_2 flux during the eruptions in August 2021 and September–October 2022 was more than 3,000 t d^{-1} and reached more than 10,000 t d^{-1}, especially in October 2022. These results indicate that the satellite monitoring of SO_2 flux using TROPOMI is an effective tool for eruptive activities at remote underwater volcanoes and volcanic islands.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Subaerial and submarine eruptions revealed by lavas and volcaniclastic rocks from the submarine flank of Mt. Etna, Eastern Sicily

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During the *RV Meteor* research cruise M198 in 2024, numerous volcanic and volcaniclastic rocks from the submarine Mt. Etna flanks were recovered by dredging in two areas: a) in the "Timpe area" off Aci Trezza at depths between about 750 and 600 mbsl (metres below sea level), and b) within the "Amphitheater area" off Torre Archirafi, located between the Timpe Plateau and the submarine Riposto Ridge, at depths between about 1100 and 800 mbsl. In both areas, we recovered phyric lavas with variable vesicle contents and grainsizes, some with glassy rinds, and fragments of volcaniclastic rocks consisting of crystalline rock fragments in a finer matrix, sometimes containing fresh volcanic glass particles. Glassy lava rinds and glassy matrix particles were analysed for major elements and the trace elements Cl and S using an electron microprobe. Timpe-area glasses show tholeiitic to transitional basalt compositions with high S contents of 300–800 ppm, likely reflecting submarine eruptions and re-deposition. These glasses are tentatively assigned to either the Basal Tholeiitic phase (>200 ka) or the Timpe phase (250–100 ka). Amphitheater-area glasses are mugearitic to benmoreitic, and compositionally overlap with Mt. Etna eruption products younger than 80 ka. They have comparatively low S contents of 50–250 ppm, indicating subaerial or shallow marine eruptions. Thus, the Amphitheater-area rocks may have subsided hundreds of meters, either by normal faulting, or alternatively involving gravitational sliding of Etna's SE flank

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Tsunamigenic landslides at Stromboli volcano: reconstruction of past events by tephrochronology

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Volcanic islands are dynamic and vulnerable environments, subject to extremely hazardous geological phenomena. Among these, volcanic landslides represent a serious threat to communities, potentially generating large tsunamis with effects that can propagate over long distances. The volcanic island of Stromboli (Italy) is well-known for its mild and intermittent Strombolian activity, alternating with rare lava emissions and more violent explosions. The activity, associated with small-volume rockfalls, debris landslides and PDCs, also includes the generation of tsunamigenic landslides from flank collapses. We present a sedimentological and compositional study of four marine sediment cores recovered from the seafloor facing the Sciara del Fuoco – a horseshow-shaped scar on the NW flank – to investigate frequency, age and magnitude of the collapse events that occurred on Stromboli over the past millennia. The chronostratigraphic succession of volcaniclastic turbidites, which have formed by the landslides, as well as the time span that is covered by the cores[MOU1] , are constrained by the intercalated primary tephra layers recognized in the sediments, for which both source and age could be unequivocally identified. The analyzed compositions of the turbidite layers mostly show a single-source origin, well compatible with current and past activity of the volcano and representative of potential small-to-large-scale landslides that occurred on the island. At least 11 landslide events have been identified within the past 10,000 years in the core closest to the island. Turbidite deposits correlate well with other marine cores farther from the island and with onshore deposits, suggesting the occurrence of significant tsunamigenic collapses.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

PRISMAC: Analysis, mitigation and management of the risk of slope movements enhanced by climate change in the volcanic archipelagos of the Macaronesia

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The sustainable development of the outermost regions, where adverse meteorological factors, whether or not enhanced by climate change, are at the origin of environmental imbalances in ecosystems and natural disasters, requires a set of sophisticated analysis of the surrounding processes to understand, analyze and mitigate them. The geomorphological evolution of volcanic islands is determined by geomorphological processes, in particular slope movements, which represent a serious constraint for human activity and ecosystems. Moreover, they constitute a considerable source of risk for people and property, and it is therefore crucial to strengthen their knowledge and to increase resilience and adaptive capacity to this climate-related risk. The main objective of PRISMAC project is to analyze, mitigate and manage natural hazards, particularly the risk of slope movements enhanced by climate change in oceanic volcanic islands in the Macaronesia region. The objective of the project is to develop and harmonize methodologies to analyze susceptibility and risk to slope movements with a view to identifying risk sites for the development of slope movement monitoring, warning and alarm systems, at local and regional scales, for each of the regions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Seismic microzonation of San Cristóbal de La Laguna (Tenerife, Canary Islands)

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We present a high-resolution seismic microzonation study of San Cristóbal de La Laguna town (Tenerife, Canary Islands), a UNESCO World Heritage Site. This is the second most populated city on the island, with the town composed mainly of 1–3 story buildings. Part of the urban area is inside a valley filled with volcano-sedimentary and lacustrine deposits. The city is also located in a seismically active region, primarily due to the island's volcanic activity. Therefore, it is prone to very shallow earthquakes with magnitudes exceeding 4.0. Henceforth, these facts make it essential to evaluate the local seismic hazard. For this reason, in 2019, we performed a seismic survey using mini-arrays of 3–4 stations at 467 locations to record microtremor for 2 hours. We applied the horizontal-to-vertical spectral ratio (HVSR) method to determine dominant site frequencies. Data were divided into 80-second windows, filtering out noise and analysing the response in the frequency range of 0.25–30 Hz. The HV curves obtained were inverted to estimate the shallow geological layer's thickness and seismic wave velocities. The first results show fundamental frequencies ranging from 0.62 to 11.11 Hz. Low frequencies (1–3 Hz) dominate most of the valley from NE to SW, likely linked to thick volcano-sedimentary and lacustrine deposits and large lava flow layers. High frequencies were observed in the central area, where the historic buildings are currently located and where an old lagoon existed. Double-frequency peaks were observed and associated with thin surface layers of silts and clays that correlate well with geotechnical observations.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Etna's submarine flank morphology: new insight from autonomous underwater vehicle microbathymetry

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Mount Etna, one of Earth's most active volcanoes, reaches an elevation of 3 400 meters, with its eastern flank extending seaward and descending to approximately -1 500 meters below sea level, creating a total vertical relief of nearly 5 000 meters. While it is now well established that Etna's offshore flank is highly mobile, the seafloor morphology and its associated structures remain poorly understood. For example, the northern bounds of the mobile sector remain unknown. In this study, we present new high-resolution multibeam echo sounder (MBES) data collected by the AUV ABYSS during the M198 research cruise aboard RV METEOR in February 2024. The data reveals previously unidentified structures and lineaments across 27 km^2 in the central part of the submarine flank. Our analysis highlights various features including erosional surfaces, steep slopes, cliffs, canyons and landslide scars. We document extremely rough morphology in and near a canyon draining Valle di Archirafi east of the Timpe plateau, also exhibiting several potential fault structures that may represent bounding faults to the mobile sector. The data shows positive relief along the steep walls of the so-called amphitheatre structure, which may indicate the presence of lava flows, suggesting parts of the structure to be of volcanic origin. This provides new aspects on the extent and evolution of Mt. Etna activity.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Axial Seamount is forecast to erupt sometime in 2025. Has it happened already or not?

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Axial Seamount is a submarine basaltic hotspot volcano superimposed on the Juan de Fuca Ridge in the NE Pacific Ocean. For the last 30 years, it has had a repeatable cycle of inter-eruption inflation and co-eruption deflation, measured by bottom pressure recorders. Eruptions in 1998, 2011, and 2015 suggest that Axial erupts at a similar level of inflation each time. We have tried to use this pattern for long-term eruption forecasting, with mixed success. Since 2014, inflation and seismicity at Axial have been monitored in real-time by a network of sensors on the NSF-funded Ocean Observatories Initiative Regional Cabled Array (OOI-RCA). From 2015-2023 the rate of inflation was highly variable, and the rate of seismicity remained at relatively low levels (~10/day). Multiple eruption forecast windows issued between 2019-2023, later had to be modified due to the continually decreasing rate of inflation. However, since the beginning of 2024, both inflation and seismicity have increased markedly, suggesting that the volcano may finally be building up to its next eruption. Axial is now near its 2015 inflation threshold, it is inflating at a rate of 20-25 cm/yr, and the rate of seismicity has been elevated since the beginning of 2024, with up to 100s of earthquakes per day. These factors led us to update our eruption forecast in July 2024 to say that Axial is likely to erupt before the end of 2025. At IAVCEI, we will present an update on the monitoring data from Axial. Will it have erupted by July 2025?

Theme: 2. Pre and syn-eruptive monitoring

Session 2.2: Surveying oceanic volcanism & volcanic island geohazards: Recent lessons & future developments

Allocated presentation: Poster

Tsunami hazards in the Mediterranean: A Greece-wide scoring for potentially hazardous coastal areas and volcanoes based on geomorphology and InSAR data

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Multi-Marex aims to detect and assess the risk and hazard potential of tsunamis in the Mediterranean Sea. To this aim, we develop a collapse hazard-scoring system and analyze the coastal areas of the entire Aegean Sea. We use topographic data from the EU-DEM (European Digital Elevation Model) to determine the slope and elevation of coastal zones, locally complemented by high-resolution drone photogrammetry data. This geomorphological database is combined with the deformation time series from the EGMS (European Ground Motion Service) InSAR catalogues and expanded by information on potentially weakened rocks, hydrothermal alteration, or volcanic activity. It will be further linked to known fault locations and earthquake data using the Seismotectonic Atlas of Greece and evaluated in the context of the local tectonic setting. This will provide a database of information on potentially hazardous coastal areas, justified by key parameters such as ground motion, high elevations, steep slopes, and proximity to the coastline. We show that sites of high hazard scores are widely distributed, and include volcanoes, eroded cliffs, and other landforms. Our aim is to provide basic information to focus further research on sites with high hazard potential based on physical parameters.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk [Invited]

Towards near-real time monitoring of volcanic deformation and lava flow mapping using Capella SAR images

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Syn-eruptive monitoring of volcanic deformation and surface changes is crucial for timely hazard assessment. Spaceborne Synthetic Aperture Radar (SAR) can reliably provide visually-interpretable images of volcanic edifices at high spatial resolution during day and night, regardless of the weather conditions. Yet, most traditional change detection methods only work between SAR images acquired by the same sensor with the same observation geometry, preventing revisit times of less than several days. Here, we present a novel method for detecting and measuring syn-eruptive topographic changes on a sub-daily basis using (i) Capella Space high-resolution SAR images acquired with varying geometries during the eruption, that we compare with (ii) a high-resolution Digital Elevation Model acquired years before the eruption. The syn-eruptive SAR amplitude image is correlated against a synthetic image generated from a radiometric terrain model combining the knowledge of the SAR sensor geometry and pre-eruptive topography. The cross-correlation score is used for lava flow mapping, which enables to track the progress of lava flows over time with daily or even sub-daily temporal resolution. Estimated offsets between real and synthetic images provide two independent components of the ground displacement field (in the line-of-sight and in azimuth). Combining multiple images acquired with different viewing geometries gives access to the three components of the displacement field. We apply the method to the Piton de la Fournaise volcano, validating the results against ground-truth data from the OVPF observatory, including daily-resolved lava flow maps produced from traditional approaches and GNSS displacement vectors from permanent and campaign stations.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

Insights into the 2018 Mayon Volcano eruption from ground deformation measurements

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Mayon Volcano in southeastern Luzon, Philippines, has exhibited the gamut of effusive to explosive eruptions since the earliest account of its unrest in AD1616. These events produced volcanic hazards that resulted in human casualties and socio-economic losses. In January 2018, the volcano suddenly entered a period of eruption that began with a series of summit lava dome collapses and minor ash explosions before escalating into brief episodes of moderately explosive eruption and lava fountaining. This latter activity was accompanied by an increase in seismicity and sulfur dioxide (SO2) degassing but was preceded by a period of aseismic and mere background degassing activity. In contrast, ground deformation measurements from continuous Global Navigation Satellite Systems (cGNSS), electronic tilt, and precise leveling campaigns already tracked inflation of the edifice as early as January 2017, as magma intruded and migrated in the subsurface. This study focuses on the results of ground deformation monitoring of Mayon Volcano from 2017 to 2018 before and during its eruption. Notably, vertical displacements derived from cGNSS data using GAMIT/GLOBK showed an increase of approximately 10 and 31 mm on the northern and eastern flanks, respectively, during this period. Radially outward horizontal station velocities also indicated an inflating body that propagated from a pressurization source beneath the northern flanks as determined from modeling using the MATLAB-based dMODELS. The results of this study provide a better understanding of the precursory ground deformation behavior of Mayon Volcano for similar eruptions especially those that are particularly lacking in seismic and volcanic gas precursors.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

InSAR as an Operational Tool for Monitoring U.S. Volcanoes

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Interferometric Synthetic Aperture Radar (InSAR) has served as a reliable research tool for studying volcanic unrest and eruptions worldwide for over two decades. Its operational use as a geodetic monitoring tool at volcano observatories, however, has often been limited by high data latency and challenges in rapid data processing. The U.S. Geological Survey Volcano Science Center (USGS-VSC) is developing an automated InSAR processing system for near-real-time monitoring, leveraging low-latency SAR data from current and future satellite missions (e.g., Sentinel-1, COSMO-SkyMed, RADARSAT-2, NISAR). This system autonomously retrieves newly acquired data from international space agencies, often within two hours of acquisition. It processes these data into accessible products and distributes them through an interactive visualization platform to experts at various USGS observatories. This capability also supports the Volcano Disaster Assistance Program in responding to volcanic events outside the United States. In this presentation, we will detail the rationale behind the USGS-VSC InSAR processing system and demonstrate its operational application through recent events at Kīlauea, Hawaiʻi. Notable examples include the Southwest Rift Zone dike intrusion and eruption in January–February and June 2024, respectively, along with multiple dike intrusions in the East Rift Zone that culminated in an eruption in September 2024. While challenges remain in applying InSAR to some volcanoes in the United States, primarily due to heavy vegetation and seasonal snow cover, new data analysis algorithms are being explored to maximize data coverage and improve monitoring capabilities at all USGS volcano observatories.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

Relationship Between Deformation and Explosive Eruptions at Rincón de la Vieja Volcano, Costa Rica Detected Using GNSS

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Rincón de la Vieja volcano is a highly active volcano hosting a complex magmatic-hydrothermal system and between July 2021 and December 2023 experienced hundreds of phreatic and phreatomagmatic eruptions. Volcanic deformation typically focuses on magmatic systems where inflation due to magma injection is an important indicator of potential eruptive activity. Meanwhile, phreatic eruptions due to the sudden flashing of trapped water without the eruption of magma result in deformation is at a much smaller scale. This study finds that multiple scales of deformation are occurring at Rincón. A GNSS network set up and maintained by OVSICORI includes stations located 1 km southwest, 5 km northwest, 6 km northeast and 5 km southwest of the active vent. Periods of long-term inflation were detected between January and June 2022 (6 months) as well as between December 2022 and November 2023 (11 months). These periods resulted in up to 32 mm and 40 mm of inflation respectively which modelling indicates is the result of a deep magma body 7-11 km below the vent. Additionally, these windows are associated with periods of significant eruptive activity. Before, during and after these periods, shorter periods of inflation lasting 20 to 40 days occur resulting in up to 30 mm of inflation resulting from pressurization of a source within the shallow (1-1.5 km below the vent) hydrothermal system. These findings indicate that several processes, shallow hydrothermal and deeper magmatic, are occurring at times sequentially or simultaneously to produce the observed deformation and eruptive activity at Rincón.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

Monitoring Volcanic Deformation Using InSAR: Deformation Time Series at Seasonally Snow-covered Volcanoes

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Satellite-based Interferometric Synthetic Aperture Radar (InSAR) is widely used for volcanic deformation monitoring, particularly since Sentinel-1 launched in 2014, providing scientists with an unprecedented volume of openly-available data. Automatic processing and analysis systems process raw satellite data into interferograms and calculate deformation time series. However, snow often leads to coherence loss in interferograms, resulting in unwrapping errors and affecting monitoring accuracy, especially for automated systems. Here, we use MODIS MOD10A2 snow cover products to identify volcanoes that experience seasonal snow cover and find that roughly half have a snow persistence of 7-90%, primarily in high-latitude and high-altitude regions. Here we focused on Laguna del Maule (LdM), Chile which has been steadily uplifting since 2007 and is characterized by seasonal snow cover (snow persistence of 73%) and steep-sided lava flows. Automated LiCSBAS products underestimate the line of sight deformation rate by 26% at GPS site MAU2. First, we test the ability of MODIS MOD10A2 snow maps to predict InSAR coherence, and found an average accuracy of 78%, peaking at 99% during early winter, confirming that low coherence is primarily caused by snow cover. We then adapt the LiCSBAS processing strategy by generating long time-span summer-to-summer interferograms and applying a re-unwrapping algorithm. This changes the observed uplift rate and improves the agreement with the GPS observation. This study shows that MODIS snow cover products can predict interferogram coherence, helping to improve InSAR auto-processing efficiency. Furthermore, we demonstrate the importance of adjusting global-averaged parameters of processing system according to regional characteristics.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

Using high spatial and temporal InSAR time series to image magmatic and flank instability processes

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Imaging localized and/or slow (< a few cm/year) deformation processes can be challenging using regular Interferometric Synthetic Aperture Radar (InSAR) datasets with relatively low spatial (> 10 meters) and temporal (> 12 days) resolutions. These limitations can be overcome by using InSAR time series approaches and higher spatial resolutions SAR sensors such as the COSMO-SkyMed satellites constellation. Here, we show two case studies in which we processed hundreds of Synthetic Aperture Radar (SAR) images acquired by Sentinel-1 and COSMO-SkyMed to reveal: 1/ a decade of ground deformation for a ~0.5 km diameter area around the summit crater of the only active carbonatitic volcano on Earth: Ol Doinyo Lengai in Tanzania; and 2/ long-term decadal flank motion prior to the 2018 catastrophic collapse at Anak Krakatau, Indonesia.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

Structural control of subsurface processes using a finite-element-based dynamic model of mid and short-term crustal evolution at Krafla volcano.

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The Krafla Volcanic System (KVS) in northeast Iceland has been one of the world's most studied volcanoes since its last eruption, the Krafla Fires (1975-1984), and during its on-going geothermal exploitation. In 2009, the Icelandic Deep Drilling Project (IDDP) discovered a previously undetected shallow rhyolitic magma body despite extensive studies in the area using geophysical methods. The large gravity and ground deformation dataset compiled at the KVS since 1975 provides unprecedented insights into the evolution of the magmatic and hydrothermal systems. While the eruptive period has been extensively studied using geophysical methods such as ground deformation, seismology, and gravity, the relationship between the magmatic system's evolution and changes in the gravitational potential field remains poorly understood. To understand the structural control of the KVS, we build a 3D finite element model of the gravitational and ground deformation changes caused by the magma infill and withdrawal from a shallow reservoir. We impose a crustal structure using observed topography and assuming a layered medium derived from seismic tomography. Testing different source geometries of the shallow reservoir allows us to replicate better the gravity and height changes observed during the eruptive event. Subsequent work aims to establish plausible combinations of dimensions and density contrast of the magmatic body encountered by the IDDP-1 from gravity measurements. The findings will enhance our understanding of the structural control of the magmatic system at the KVS and may provide valuable insights for future geothermal exploration projects.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

Tectonic stress release through dike emplacement constrained by surface deformation: Finite Element modeling of the 2021 Fagradalsfjall dike, Iceland

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At divergent plate boundaries, tectonic stress accumulates due to plate motion over time and may be released through rifting episodes and dike emplacement. Although the importance of tectonic stress for magmatic intrusions in this context is well known, it is rarely directly considered in surface deformation models. In 2021, a magmatic dike formed in the Fagradalsfjall volcanic system, SW-Iceland, ending almost 800 years of volcanic quiescence on the obliquely spreading Reykjanes Peninsula. Dike emplacement was accompanied by intense seismicity and ground deformation, which was geodetically well documented. We implement a Finite Element deformation model to explore and quantify the contribution of tectonic stress as a driving mechanism for dike emplacement, using the 2021 Fagradalsfjall dike as a case study. First, tectonic stress accumulates due to oblique plate motion in a viscoelastic model. Secondly, dike opening locally releases a part of the accumulated tectonic stress. We found that geodetic observations can be reproduced reasonably well when ca. 60% of the accumulated tectonic stress is released. In oblique tectonic settings, shearing above the dike may help to distinguish between dikes driven largely by tectonic stress or by magmatic overpressure. Tectonic stress as the dominant driving mechanism for dike emplacement at Fagradalsfjall in 2021 is consistent with low magma flow rates at the onset of the eruption and partial stress release is consistent with subsequent dike intrusions between 2021-2023. Our model helps to better understand volcano-tectonic interaction on the Reykjanes Peninsula and to consistently model stress release constrained by surface deformation.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

On the ground deformation of Campi Flegrei and Vesuvio since 1993 using SAR data

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Naples, Italy, lies between the Campi Flegrei and Vesuvio volcanoes in one of the world's most dangerous regions. After 3,000 years of dormancy and centuries of subsidence, Campi Flegrei erupted in 1538, preceded by increasing seismicity and uplift. Since the 1950s it has experienced intermittent unrest, with four major episodes; the 1982-1984 episode was followed by prolonged subsidence. Uplift has been continuous since the early 2000s. The last Plinian eruption of Vesuvio occurred in 79 AD, followed by sub-Plinian eruptions in 472 and 1631, and semi-persistent activity until 1944. The eruptive histories of Campi Flegrei and Vesuvio are different, and the products erupted in the past have different characteristics, but they are compatible with the possible existence of a common 8-10 km deep magmatic layer. Geophysical studies support the existence of this layer. Recent studies have used ERS/ENVISAT (1993-2010) and Sentinel1 (2015-present) SAR data to show that ground deformation during the uplift of Campi Flegrei was partly due to sources about 8 km deep, that a deep depressurisation occurred beneath Vesuvio in the early 2000s, and that possible deep interactions between the two volcanoes occurred between the subsidence and uplift of Campi Flegrei. For 2010-2015, ESA's PP0094512 project has made it possible to generate deformation time series from Radarsat2 images over the entire volcanic area, using a specific procedure based on various free or open source software. The results obtained by combining the ERS/ENVISAT, Radarsat2 and Sentinel1 data are presented, in particular the evolution of non-moving, statistically independent deformation sources.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Talk

Laccolith deformation, pit craters, and caldera subsidence at Puyehue-Cordón Caulle, Chile (2011-2024): Integrating InSAR, high-resolution topography and optical imagery

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The 2011-2012 Puyehue-Cordón Caulle eruption generated surface modifications that continue to evolve. While previous studies documented first-order deformation patterns including inflation from a magma chamber and uplift and subsidence of a laccolith, the spatiotemporal evolution of surface changes around the eruptive vent and 6km away at Puyehue volcano remains poorly constrained. We employ multi-temporal InSAR analysis spanning 2011-2024, coupled with high-resolution DEMs and optical images to quantify surface property changes. Our detailed analysis of the laccolith reveals the development of both extensional fractures and pit craters exhibiting distinct morphological evolution. The fracture network shows progressive development radiating from pit crater centers, with individual fractures extending 100-500m in length. Pit craters range from 10-50m in diameter and reach depths of 30m, demonstrating ongoing structural adjustment of the shallow magmatic system. Initial rapid subsidence of up to 19m/yr was observed in both the laccolith and tephra deposits until February 2013, followed by slower subsidence of all deposits until 2019, with tephra deposits reaching thicknesses of 10-50m. Independently, at Puyehue caldera, analysis of new Pleiades DEMs (0.5m) acquired in 2024 documents sustained but decreasing subsidence rates, transitioning from -7.7m/yr (2016-2019) to -2.4m/yr (2019-2024). This 40% reduction in subsidence rate, coupled with the progressive development of concentric ring fractures (2.5km in diameter), provides important constraints on the source mechanisms driving continued surface deformation within the caldera. We demonstrate how integrating multiple remote sensing datasets enables detailed characterization of post-eruption changes, with applications to monitoring active laccoliths at Usu volcano, Japan and Mount St. Helens.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Gravity Observation During 2021-2023 and Magma Activity in Changbaishan-Tianchi Volcano,China

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The Changbaishan-Tianchi volcano(CBV) is one of the most active and hazardous volcanoes,which has experienced one of the largest Holocene eruptions around the year 946 CE. A series of volcanic unrest events in 2002-2005. Another low-level unrest occurred from December 2020 to June 2021. The Second Monitoring and Application Center, CEA selected and measured 29 gravity stations in the north and northwest flanks. The surveys were conducted with 2 Burris gravimeters in July 2021, August 2022, and August 2023. The results show that the gravity changes during 2021-2022 is -161.4uGal to 23.4uGal. The most of them are negative and the values are greater than 50uGal. The variations during 2022-2023 is -37.8uGal to 135.7uGal. The most of them are positive. The majority are less than 50uGal. The values of the several stations located in the northern flank are greater than 50uGal. The stations with more than 100uGal are generally located within 12km of the volcano center. The station with the largest gravity variations is located on the west flank, indicating a fault passing nearby. The variations during 2021-2023 are from -90.6uGal to 56.0uGal, mainly with negative values. According to the observed results of earthquake and deformation, the CBV activity is weak. Based on the magma structures in the crust and mantle, we speculate that the magma activity mainly occurred between the interconnected magma conduits,sills and faults. The conjoint analysis of gravity and deformation results also indicates that magma intrude/drain in existing void/space of chambers or faults.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Multidimensional Small Baseline Subset (MSBAS) Software for constrained and unconstrained deformation analysis of partially coherent DInSAR and speckle offset data

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Differential Interferometric Synthetic Aperture Radar (DInSAR) and speckle offset data are used to measure ground deformation. Computing deformation time series from these data can be challenging due to varying radar line-of-sight acquisition geometry, rapid coherence loss, and the large datasets involved requiring computationally intensive processing. The Multidimensional Small Baseline Subset (MSBAS) Software is designed to compute deformation time series from these data, and its parallelized version is optimized to handle large datasets from modern SAR satellites. The software can produce 1D, 2D, and 3D Surface-Parallel and Aspect-Parallel Flow constrained and 3D unconstrained or 4D deformation time series. It runs on workstations and clusters utilizing OpenMP and MPI/OpenMP. This study presents novel results demonstrating MSBAS capabilities.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Modeling deformation and gravity changes from arbitrary positioned point inflation source beneath conical terrain

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Geodetic observations and modeling play a vital role in understanding magma dynamics, crustal stress distribution, and predicting potential volcanic hazards. Accurate modeling of surface displacements and gravity changes induced by magmatic sources provides invaluable insights into subsurface structures and dynamics. Historically, a wide range of models has been developed to describe volcanic deformation. Among these, the Mogi model, which assumes a point spherical inflation source in an elastic half-space, has been extensively employed due to its simplicity and explanatory power. In this work, we extend the Mogi model to an infinite conical topography, where a point inflation/deflation source is embedded at an arbitrary position inside the elastic cone. We have successfully derived a semi-analytical solution to the three-dimensional elastostatic problem using Mellin and Fourier transformations. The accuracy of our solution is verified by comparisons with finite-element methods across several scenarios. A prominent characteristic of our cone model is that the surface displacements and gravity changes expected near the summit are enhanced compared to the Mogi source with the same volume change and depth. The proposed method serves as a useful first-order approximation for addressing topographic effects on the deformation field. The flexibility in source positioning enabled by our model allows for diverse applications, including source parameter inversion from geodetic data.
References: https://doi.org/10.1093/gji/ggac379 https://doi.org/10.1093/gji/ggae146

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Characterisation of activity at Semeru volcano using high resolution radar and optical imagery

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The Semeru volcano, located in eastern Java, Indonesia, reactivated in December 2021 following by the collapse of a dome that had been growing since 2009. Monitoring its summit surface evolution is essential, but can hardly rely on ground-based measurements only, because of the edifice's inaccessibility and high sensors costs. Synthetic Aperture Radar interferometry (InSAR) overcomes these challenges by enabling high-resolution mapping of ground deformation and topographic changes. Studying volcano deformation at Semeru using InSAR is challenging. The steepness of the edifice, the tropical climate and its evolution through volcanic processes create significant noise in the InSAR phase. These effects can mask low-amplitude deformation signals, requiring corrections. To improve detection of low-amplitude displacement signals, we combine high-resolution SAR acquisitions from the TerraSAR-X, TanDEM-X, and PAZ missions, with data for the period 2022-2024. First, high-resolution DEMs are produced from eight TanDEM-X bistatic acquisitions and a Pleiades image. It enables to characterize dome evolution from 2015 to July 2021. During this period, the dome evolves heterogeneously, increasing 50 meters in height and reaching 1.35 million cubic meters in volume. Lava flows and pyroclastic deposits accumulate with a thickness up to 75 meters, filling trenches and creating new deposition channels eastward. Then, for TSX and PAZ repeat pass interferometry, we use the produced DEM to correct topographic fringes and we mitigate atmospheric delays using the ERA-5 weather model and GNSS dataset. By combining those three datasets, we expect to reduce noise in InSAR time series and therefore improve the detection of low amplitude signals.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Formation of the donut-shaped lava dome at Nevado del Ruiz volcano studied using TerraSAR-X, thermal imagery, and analogue modelling

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Lava domes often develop flat-topped or even ring-shaped morphologies that are only poorly understood. The Nevado del Ruiz volcano in Colombia, notorious for its catastrophic 1986 eruption, has been experiencing a new episode of dome extrusion in 2016-2017. Here we exploit high-resolution spotlight synthetic aperture radar data acquired by the TerraSAR-X satellite, allowing us to monitor the dome at regular intervals. We compare the data to thermal anomaly data, and trace the ~400 m diameter dome growth. Specifically we can distinguish (i) an initial radial growth and thermal peaks both at the dome's apex and its periphery, and (ii) a cooling, flattening and subsidence of the dome's apex, forming a donut-shaped dome feature. To better understand the transition from growth and expansion to subsidence and contraction, we conducted analog experiments simulating conduit extrusion leading to dome formation followed by conduit withdrawal. Experimental results show during dome extrusion a vertical growth and mainly radial expansion, accompanied by oversteepening of the outer rim and localized peripheral collapses. In contrast, conduit withdrawal causes the apex of the dome to contract and subside, forming localized concentric fault traces. We conjecture that areas of expansion and collapse amphitheaters corresponded to zones of intense thermal anomalies and dome growth, whereas areas of contraction correlated with cooler regions, signifying a transition from dome growth to cooling and subsidence. This study underscores the importance of exploring the evolution of lava domes and the formation of donut-shaped morphology that may be similarly found at dome building volcanoes elsewhere.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Deformation dynamics on a topographic high: Insights from Mount Thorbjörn, Southwest Iceland, during the 2023-2024 Svartsengi volcanic crisis

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Deep magmatic processes induce deformation patterns that depend on near-surface structural features. Topographic highs and pre-existing weaknesses tend to localise and amplify crustal deformation, making them essential factors to consider when applying geodetic methods and assessing related hazards. There are few studies detailing the link between topography and fracturing, therefore limited insights into this interplay. Real-time deformation monitoring at Mount Thorbjörn, a faulted and fractured 200-meter-high table mountain in the currently active Svartsengi Volcanic System, provides a unique opportunity to observe topography-fracturing interactions and evolution. We collected four drone photogrammetric datasets between 2022 and 2024, covering different stages of the volcanic unrest. We compare centimeter-resolution orthophotos and digital elevation models and identify the reactivation of pre-existing graben systems in November 2023, with individual faults showing dip-slip of up to ~80 cm and dextral strike-slip of up to ~30 cm. Vertical displacements are more pronounced in the southeastern sector, suggesting a local tilting of the edifice consistent with the main November 2023 graben. Orthophoto comparison allows us to map almost 10 km of new cumulative surface fractures and over 100 sinkholes, 88% of the fractures and 50% of the sinkholes formed during the November 2023 graben event. Statistical analyses and sandbox analogue experiments show how fracture density and geometry correlate with topography, with higher areas experiencing more and intense fault reactivation, surface cracking, sinkholes and slope instabilities. We provide a generalized conceptual model for fracture development in complex volcanic landscapes, helpful to anticipate potential impacts in volcanic systems elsewhere.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Enhancing Global Volcano Monitoring: Refining LiCSAR and LiCSBAS Workflows with Coherence Statistics

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Volcano deformation monitoring is crucial for understanding magmatic processes and assessing volcanic hazards. Satellite systems such as Sentinel-1 provide regular, global, and open-access data, enabling continuous observations even in remote or hazardous areas. Automated and open-source processing systems, such as LiCSAR/LiCSBAS (https://comet.nerc.ac.uk/comet-volcano-portal/), have revolutionized global volcano monitoring by providing efficient time-series deformation analysis using Sentinel-1 datasets. However, the time-series are currently produced using global default parameters, causing issues with data gaps and low coherence, which influence the accuracy and reliability of the time-series inversion, particularly in regions affected by seasonal decorrelation or sparse data coverage. To address these limitations, we refine the LiCSAR and LiCSBAS workflows to adapt to local conditions. Specifically, we integrate long-term baseline interferograms and use coherence statistics to generate high-quality interferograms, improving the temporal coverage and reliability of InSAR time-series networks. To test this strategy, we analyzed 14 volcanoes selected based on their geographic location (across continents and latitudes), snow cover, vegetation cover, and other factors affecting InSAR coherence. The study aims to demonstrate that incorporating coherence-optimized long-term baseline interferograms can improve the continuity and accuracy of deformation measurements, offering a more complete picture of global volcanic deformation dynamics. These refinements to LiCSAR and LiCSBAS workflows can significantly advance global volcano monitoring capabilities, ensuring that InSAR remains a cornerstone technique in volcanology. This work lays a foundation for more reliable and comprehensive monitoring systems, addressing both scientific needs and societal priorities in managing volcanic risks.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Near Real-Time Ground Monitoring of Natural Hazards Using FAST-SAR

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The application of radar interferometry for near real-time ground monitoring of natural hazards, such asvolcanic activity and landslides, faces challenges including latency in acquiring SAR and external datasets, lengthy processing times, and the effective correction of error sources (e.g., atmospheric delays, topographic residuals, and unwrapping errors). The French National Service for Ground Deformation Monitoring (ISDeform) aims to provide ground displacement measurements using radar and optical imagery for active volcanoes and landslides in French territories. Here, we introduce FAST-SAR, a Fully Automated radar interferometry processing system tailored for Small Targets. This system is built on the NSBAS processing chain, which utilizes the small baseline subset method. To correct tropospheric noise, FAST-SAR makes use oflocal GNSS networks to generate tropospheric delay maps, which demonstrate superior performance compared to maps derived from global weather models such as ERA5 and GACOS. For correcting DEM errors, high-resolution topographic data from Pleiades and TanDEM-X DEMs are incorporated where available.For the time series, an incremental strategy is developed to only inverse recent acquisitions dates. FAST-SAR has been tested at multiple sites, including Piton de la Fournaise and Merapi volcanoes, as well as Harmalière and La Clapière landslides. For Piton de la Fournaise, the corrected InSAR time series show strong agreement with GNSS data, revealing inter-eruptive ground displacements that may be linked to the re-pressurization of the shallow magma reservoir. At La Clapière, the InSAR time series highlight acceleration of displacements rates during the winter months or rainy events, emphasizing the influence of external forcings.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Galeras volcano conduit dynamics revealed by ALOS-2/PALSAR interferometry (2015-2023)

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The detection of precursory deformation signals presents several challenges at tropical stratovolcanoes. These challenges are related to dense vegetation, strong topography gradient, and rapidly changing atmospheric conditions that introduce noise in observations derived from ground instrumentation and satellite imagery. Moreover, the spatial resolution of GNSS networks is limited for a continuous mapping of surface displacements, and subsequent precise modeling of internal sources. These limitations were addressed by analyzing ALOS-2/PALSAR images at Galeras volcano characterized for being one of the most active ones in Colombia. Tropospheric noise correction methods were based on external datasets such as weather models and local GNSS data, and on the removal of correlated signals between elevation and deformation. Their performance at reducing noise on the interferometric phase was assessed statistically. As a result, precise cumulative displacement maps and time series were obtained for the period 2014-2023. A persistent subsiding circular signal with a radius of ~0.25 km is retrieved at the volcano's summit from ascending and descending geometries. Using the Boundary Element Method (BEM) software DefVolc, we model cumulative ground displacements on the order of ~0.08 m by a vertically elongated ellipsoidal source located at ~0.60 km depth below the main crater. Integrating additional datasets, such as seismological tomography and gas measurements, can refine the interpretation of the causes behind the volcano's conduit volume change and provide deeper insights into the current state of the magmatic system.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Facilitating satellite monitoring of unrest and eruptions through global cooperation between space agencies and volcanologists: The GVEWERS project

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The Committee on Earth Observation Satellites (CEOS) Working Group on Disasters has coordinated several projects to support volcano disaster risk management. These efforts have specifically focused on the accessibility, at no cost, of high-resolution synthetic aperture radar (SAR) and optical datasets, which are often only available via commercial purchases or limited research grants. During 2014–2017, the Volcano Pilot project focused on assessing the feasibility of integrated, systematic, and sustained monitoring of volcanoes in Central and South America using space-based observations. Multiple space agencies provided quotas of SAR and high-resolution optical satellite data, enabling regional volcano observatories to use otherwise poorly accessible imagery for volcano surveillance. The successful pilot project was followed by the Volcano Demonstrator project (2019–2023) that expanded the scope of the work to Southeast Asia and Africa. In 2023, CEOS approved the Global Volcano Early Warning and Eruption Response from Space (GVEWERS) initiative—a permanent and sustainable partnership among international space agencies, academic institutions, and volcano observatories, with the goal of coordinating the acquisition, access, and utilization of satellite data to support volcano monitoring worldwide. The project emphasizes free and low-latency access to satellite datasets that are critical for forecasting, detecting, and tracking volcanic activity, and for mitigating associated hazards around the world by providing early warning of potential eruption impacts—for example, unrest at Fentale, Ethiopia, in 2024. Support from the global volcanology community is critical to the success of GVEWERS, and international participation is invited.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Cost-effective GNSS for volcano deformation monitoring: A case study on Saba in the Caribbean Netherlands

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Volcano geodesy is considered a critical component of volcano monitoring, but the high cost of equipment often limits the deployment of a ground-based monitoring network. In regions where volcanic hazards are significant, particularly in developing nations, the use of affordable, alternative equipment can be especially beneficial. In this context, we evaluate the use of cost-effective dual-frequency GNSS units for deformation monitoring. Four cost-effective GNSS units, composed of an Ardusimple "Survey GNSS Multiband antenna" and an "u-blox ZED F9P" receiver, were deployed on Saba, a volcanic island in the Caribbean Netherlands. They are easy to install, enabling rapid setups in hazardous areas, with a total cost of < €1,000 per unit—a fraction of the cost of a conventional GNSS station. Each unit includes all necessary components for stand-alone operation, and the PCB schematics, materials list, and software are publicly available. The GNSS data of the cost-effective units can be processed operationally, either as a stand-alone monitoring network or as an expansion of an existing monitoring network. The daily positioning performance of the cost-effective units is comparable to that of conventional GNSS stations on the island, with standard deviations of 2-4 mm for the horizontal and 6-9 mm for the vertical components. We encourage the deployment of cost-effective GNSS units for volcano monitoring, to increase the density of the monitoring network or in hazardous environments where rapid installation is crucial. Finally, these units can be operated as a stand-alone network in budget constrained regions where volcano monitoring is essential.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

The triggering of sub-Plinian and Plinian eruptions: insights from three decades of InSAR observations in the Andean Southern Volcanic Zone (1991-2024) and a global compilation

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Volcanic eruptions are triggered by increases in the overpressure of the regions where magmas are stored. Hence, observations of ground deformation provide insights on the triggering mechanisms of eruptions, and in particular of sub Plinian and Plinian eruptions which are the most hazardous eruptions with a global impact. We present a compilation of ~30 years observations of ground deformation from InSAR geodesy spanning a sequence of four VEI 4-5 eruptions in the Southern Andes: Hudson 1991, Chaitén 2008-2009, Cordón Caulle 2011-2012 and Calbuco 2015. Only Cordón Caulle displays the theoretical pattern of pre-eruptive uplift, co-eruptive subsidence and post-eruptive uplift. For the rest of the volcanoes we observe co- or post-eruptive ground deformation, but the data temporal resolution is low and did not sample well all the eruptions. On a global scale, a compilation of geodetic data in subduction volcanoes that experienced eruptions of similar magnitudes indicates a dearth of data, but in a few cases geodetic data recorded the last episodes of pre-eruptive reservoir pressurization (Taal, Soufrière St. Vincent). This implies that most of the magma that increased the overpressure must have been emplaced in the decades or centuries prior to eruption. Only Okmok volcano display a ground deformation pattern similar to that of Cordón Caulle. The longer time scales of recharge in subduction volcanoes compared with those in hot spots could be indicative of larger storage regions. This compilations calls for the acquisition of InSAR data with longer wavelengths in heavily vegetated volcanoes.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Terrestrial Radar Interferometric Measurement of Surface Deformation of Halemaʻmaʻu Lava Lake, Kīlauea

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We used a terrestrial radar interferometer (TRI) from Gamma Remote Sensing to measure surface deformation of an active lava lake within Halemaʻumaʻu at Kīlauea's summit on January 19, 2023, two weeks after the eruption began on January 5, 2023. We observed a 90-minute deformation event with a maximum line of sight displacement of 35 mm. Radar interferograms were generated every 90 seconds over a ninety-minute period of intermittent inflation using a scanning real aperture radar operating at Ku band (17.4 mm wavelength). This technique allows observation of phenomena at a temporal scale (minutes), spatial scale (meters) and resolution (millimeters) that has not been previously possible. We model the intrusion as a shallow sill, 10 to 100 meters below the lava lake surface. We suggest that such intrusions are frequent and may represent the 'quanta' of processes that help to maintain the lava lake. Small volume pulses of gas-rich magma help to provide the necessary flux of heat and mass to compensate for cooling, outgassing, and recycling of dense degassed magma to deeper levels, sustaining the lava lake in a near-steady-state.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

A framework for systematic cataloguing of volcano deformation source parameters from Sentinel-1 InSAR data

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Understanding global patterns of monitoring signals at volcanoes is important for inferring magmatic processes, forecasting of eruptions and unrest, and identifying similarly behaving systems. Satellite datasets provide global volcano deformation measurements, but existing global compilations rely on metadata parameters. These are not systematic and suffer from biases and uncertainties, due to methodological differences in data and modelling. Growing archives of Sentinel-1 InSAR data, systematically measuring volcano deformation globally, now provide an opportunity to overcome these limitations. Here, we present a framework to create systematic, data-driven volcano deformation catalogues from Sentinel-1 InSAR datacubes, tested using a dataset of 16 deforming volcanoes along the East African Rift System (EARS). First, we extract temporal parameters by fitting functions to deformation timeseries. Then, we develop methods to systematically determine source parameters building on the Bayesian non-linear inversion software, GBIS. Pre-processing steps, particularly downsampling and initial model geometries, were validated with synthetic examples. We model the signals using Mogi and Penny sources and compare fits against alternate source geometries using Akaike's Information Criterion. 14/16 EARS signals were automatically located correctly and 12/16 are fit with a Mogi source, with another two signals fit best with Okada sources. Variations in source parameters correspond to differences in inferred magmatic processes and tectonic setting. For simple sources, the output parameters are within ranges of previous modelling studies, but further work is needed to develop a systematic approach for datasets containing multiple signals or deformation episodes. Applied globally, such catalogues could aid eruption forecasting and analogue volcano identification.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Deforming Volcanoes with Trans-Crustal Magmatic Systems: The Influence of Magma-Mush Heterogeneity

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Volcano deformation is a key observable to indicate volcanic unrest, conduct hazard assessments, and help forecast possible eruptions. Current volcano deformation models used to interpret deformation observations are overly simplistic; they assume static incompressible fluid-filled magmatic sources and do not account for dynamic natural processes, thus contributing to uncertainty in hazard assessments and eruption forecasts. However, magma exists in heterogeneous, vertically extensive, trans-crustal magmatic systems, variably consisting of interstitial melt contained within a porous crystal-framework, or "mush" zone. Here, we explore the influence of melt and mush heterogeneity on surface deformation during magma resupply. Our physics-based finite element models couple solid and fluid mechanics to simulate mechanical interaction between melt-filled domains, poroelastic mush zones, and solid host rocks, building on recently benchmarked solutions. Preliminary results for a spherical magma reservoir consisting of a melt-filled region overlaying a poroelastic mush indicate that: (1) initiation of surface deformation may lag the beginning of melt resupply by 1-2 years; (2) surface deformation can accelerate even after melt supply has stopped; and (3) surface deformation can continue for ~8 years after melt supply ends. These results contrast with current general understandings of volcano deformation which would typically assume ground inflation starts, and rates are highest, concurrent with magma resupply. Subsequent investigations will further explore the parameter space to understand how pervasive the temporal surface deformation patterns in the preliminary results are. Where possible, results are further illustrated with application to ongoing volcano deformation at Soufrière Hills Volcano, Montserrat.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Thermodynamic Variability in Magma Mush Reservoirs: Implications for Volcano Deformation

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Magma is likely stored in heterogeneous, vertically extensive, porous "mush" zones. A magma mush can be modelled as a poroelastic material in response to melt injection or withdrawal. An increasing number of studies consider the role of magma mush poroelasticity in analyses of volcano surface deformation and the evolution of stress around a magma reservoir. Most of these studies, however, consider constant and uniform magma mush properties in time and space. Here, we incorporate thermodynamically variable magma properties and consider their role in modulating volcano deformation, thereby also beginning to address the role of volatiles in poroelastic volcano deformation models. We utilize thermodynamic models, specifically MagmaSat and MELTS, to simulate decompression-driven H_2O-CO_2 exsolution, melt-crystal phase development, and crystallization processes in magmatic systems. These models calculate phase assemblage, crystal fraction, gas volume fraction, density, viscosity, and compressibility as functions of temperature, pressure, and composition, which are subsequently input into new deformation models. By comparing our results with previous studies that assumed uniform bulk magma properties, we will determine how thermodynamically induced dynamic changes in magma properties affect surface deformation patterns and resolve evolving internal heterogeneities.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Dynamic Numerical Modelling of Volcanic Inflation at Bárðarbunga Volcanic System, Iceland, 2015-2024

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The 2014-2015 Holuhraun eruption was accompanied by ~65 metres of collapse of the ice-covered Bárðarbunga caldera, due to ~1.9 km^3 of magma being extruded from beneath the caldera into a dyke. Post-eruptive observations indicate that the volcano began reinflating from July 2015. Deformation extends beyond the caldera, and outside the Vatnajökull ice cap. GNSS & InSAR data within a region up to ~20 km away from the caldera has been corrected for glacial isostatic adjustment and plate spreading, for the time period of July 2015 to September 2024. Vertical and horizontal deformation rates within this region range from 5 – 20 mm/yr and 10 – 50 mm/yr, respectively. Unpublished data suggests >10 metres of uplift within the caldera. Here, we use dynamic poroelastic-reservoir finite element volcano deformation models to reproduce the observed post-eruptive deformation of the Bárðarbunga caldera system and constrain magma supply and storage characteristics. The models incorporate independent geochemical and geophysical data, and model simulation involves melt injection into a poroelastic reservoir within a heterogeneous elastic crust. Preliminary results show that incorporating a caldera ring fault into the model has a significant effect on the modelled deformation field, whereby the majority of the deformation occurs within the caldera. The likely deformation source is a sill-shaped magma reservoir ~10 kilometres beneath the caldera, which coincides with the base of the ring fault. The initial thickness of the sill reservoir is unknown, but has been modelled here as 10 metres, with an opening since 2015 of >10 metres.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Repeated reactivation of the SW crater wall of Whakarri/White Island: Insights from hi-resolution Satellite Radar observations and numerical modelling.

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Over the last 500 years there have been at least 20 major edifice collapses at volcanoes around the world. Weak and over steepened slopes, active hydrothermal systems, hydrothermal alteration, and the periodic intrusions of magma, all contribute to the inherent instability of many volcanic edifices. Water is thought to play an important role in slope failures, and the pressurization of pore fluids has been implicated in the triggering of multiple volcanic flank failures. Here we present 9-years of high-resolution SAR data from Whakaari/White Island showing repeated activation of the SW crater wall. Using a combination of ascending and descending data, we extract the ~3D displacement of the slope. We identify 4 distinct movement periods, ranging duration and magnitude since 2015. Slip across recently observed tension cracks across the slope can be directly imaged by InSAR revealing up to 500 mm/yr of right lateral shear following the 2019 eruption. Each movement event corresponds to periods of heightened subsidence in and around the 2019 vent area and inferred depressurization of the shallow hydrothermal system. Using numerical models, we test the hypothesis that the depressurization of the hydrothermal system reduces the normal stresses along the landslide slip plane allowing for it's reactivation. Together, these data provide a case study for utilizing new satellite measurements to assess detailed changes at hazardous and remote volcanic systems, helping to supplement the array of monitoring tools available to volcanologists.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Challenges and solutions in geodetic monitoring of submerged volcanoes in shallow waters: the Campi Flegrei case study

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In coastal areas characterized by limited sea depths, various factors make it challenging to conduct measurements using permanent seafloor instrumentation. These include: 1) significant biological growth on the instruments, which can alter their functionality after just a few months (this requires periodic recovery and repositioning of the instruments near their original location); 2) fishing activities that can displace or even remove the equipment; 3) high variability in the physical properties of the water column. These challenges make it difficult to apply standard marine geodesy techniques, which primarily rely on acoustic methodologies. Consequently, new methodologies have been developed to monitor seabed deformations in the Campi Flegrei area. To this end, a permanent infrastructure for geophysical monitoring of volcanic activity in the Campi Flegrei marine sector (Gulf of Pozzuoli) has been installed, consisting of four buoys. Various methodologies are used for geodetic monitoring, including precision pressure measurements at the seabed near each buoy, sea level measurements via a tide gauge on one buoy, and GPS receivers mounted on top of each buoy. Each of these sensors has been operating continuously from 2016, contributing to the definition of the ground deformation field in the Gulf of Pozzuoli. The presentation will discuss the main techniques for measuring seafloor ground deformation, the solutions implemented in the Campi Flegrei area, and the results obtained over nine years of continuous measurements in the region, as well as future developments.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

2023-2024 inflation-deflation cycles at Svartsengi and repeated dike injections and eruptions at the Sundhnúkur crater row, Reykjanes Peninsula, Iceland

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Since 2020 a series of inflation-deflation cycles have occurred in the center of the Svartsengi volcanic system, SW-Iceland. Since 27 October 2023, continuous inflation has been interrupted by deflation periods when nine dike injections and seven eruptions have occurred from 10 November 2023 to 8 December 2024 at the Sundhnúkur crater row and its extension. Geodetic modelling, assuming a deformation source within a uniform elastic half-space, infers pressure changes between about 3-6 km depth, with inflow causing volume increase rates of 3-8 m^3/s. The deflation periods began rapidly triggering a dike propagation from the northeastern edge of the Svartsengi magma domain. Geodetic modelling has been undertaken in near real-time utilizing rapid estimates of ground displacements mapped by GNSS (Global Navigation Satellite System) geodesy, using deformation sources in fixed locations. Additional geodetic inversions also use extensive interferometric analysis of synthetic aperture (InSAR) satellite images. These results have been used to map the locations and volumes of the intruded dikes and the concurrent volume drop in the magma domain. Since 27 October 2023, we infer continuous inflow of magma from depth into the magma domain, which appears to continue even during outflow into dikes and the extrusion of lava flows. We analyze all the inflation-deflation cycles, to better understand the mechanisms controlling the activity. The relationship between volume loss in the magma domain during these events and subsequent volume recharged to the reservoir (before the next event is triggered) has allowed success in forecasting diking/eruption onset in the medium and short term.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

A hydromechanical deformation model for Deception Island caldera, South Shetland Islands

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Deception Island (DI) is 13 km wide active caldera in the South Shetland Islands, popular for polar research and Antarctic tourism. Ground deformation monitoring in the austral summer since 1999 shows 3-to-6-year inflation-deflation cycles, hypothesised as resulting from hydrothermal activity. Evidence supporting an active DI hydrothermal system includes heated soils and waters, fumaroles, bubbling gases, and gaps in an otherwise island wide permafrost. Deformation modelling at DI is currently limited, and thus far has not examined the role of hydrothermal unrest. We use numerical modelling to investigate how fluid injection in hydromechanical models, using DI topography and inferred subsurface structure, influences simulated unrest. Our models test varying subsurface structures, ranging from a homogeneous basalt to a heterogeneous crust with vertical and horizontal contacts. Different fluid injection locations and the influence of a high porosity ring fault are also investigated. We show that altering the model's subsurface geology and structural properties, including the fault, strongly influences the ground surface deformation: heterogenous models show reduced ground surface displacement compared to a homogeneous model; adding the fault focuses deformation within the caldera; while adding fractured basalt to the caldera base flattens the maximum deformation region across the model interior bay. Our results also indicate that fluid injection location strongly controls the spatial deformation pattern. Despite this, using a more geologically heterogeneous model configuration reduces the deformation differences caused by different fluid inlet types, indicating that fluid injection placement and use of heterogeneous subsurface geology should be considered when building hydromechanical models.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

The Government of Canada's First Dedicated Volcano Monitoring System Using InSAR Technology

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The west coast of Canada is home to 348 known volcanic vents Pleistocene in age or younger, at least 54 of which were active in the Holocene. Recent, noteworthy eruptions include the ~220 BP eruption at Tseax Cone which has been estimated to have caused approximately 2000 casualties from the Nisga'a Nation and the ~2360 BP Plinian eruption at Mt. Meager which had an estimated Volcanic Explosivity Index of 4. In 2021, the Geological Survey of Canada published a volcano threat ranking utilizing the methodology defined by the United States Geological Survey's (USGS) National Volcano Early Warning System. Two volcanoes, Mt. Meager (Qw'elqw'elústen) and Mt. Garibaldi (Nch'k̲ay̓) ranked in the 'Very High' threat category while three additional volcanoes ranked in the 'High Threat' category. At the time of the study, no routine monitoring for magmatic unrest was conducted by the federal government. In 2019, the RADARSAT Constellation Mission (RCM), Canada's newest generation of Earth observation satellites was launched into orbit. We demonstrate how this Synthetic Aperture RADAR (SAR) system is used to provide a cost-effective wide area monitoring system for magmatic unrest detection in Canada. We describe the cloud-based infrastructure of the fully automated InSAR monitoring system and how it ingests, processes, stores and disseminates InSAR deformation results for interpretation. We discuss the implications of high temporal revisit InSAR on temporal decorrelation and maximum observable displacement rates and present select results from the RCM Global Volcano Watch Background Mission used to validate the system performance.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Characterizing Unrest at the Chiles-Cerro Negro Volcanic Complex Using Time-Lapse Gravity Data

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The Chiles-Cerro Negro Volcanic Complex, located on the Ecuador-Colombia border, has exhibited unrest since early 2022. Observed phenomena include 8 cm of uplift near the Chiles edifice, seismic swarms, and mild superficial changes in thermal springs. Nearby, the Potrerillos caldera (10 km south) has shown significant ground deformation, with uplift reaching 60 mm/year. To investigate these activities, gravity monitoring began in June 2022. Surveys covered six sites on Chiles' southern flank and five near Potrerillos. Between July and October 2022, gravity measurements at Chiles indicated a 65 µGal decrease, followed by an equivalent increase by April 2023. After April, gravity changes near Chiles stabilized, while Potrerillos' sites showed a continuous gravity increase reaching up to 45 µGal, alongside ongoing uplift through November 2024. Preliminary results from inversion of geodetic datasets show evidence for two different sources of mass change: a loss of more than 3×10^{11} kg occurred in Chiles' southern flank between July and October 2022, followed by a similar mass increase in the following months. Additionally, a continuous mass gain 10 to 15 km below Potrerillos Caldera was modelled, with a maximum increase of 7×10^{12} kg between July 2022 and November 2024. Two potential scenarios explain these observations: (1) a single magmatic source near Potrerillos driving fluid migration towards Chiles along fault systems, resembling the 2014 unrest, or (2) two independent sources of mass change beneath Chiles and Potrerillos. By analyzing gravity data, we aim to identify the most likely scenario and its implications for volcanic activity forecasting.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Pre- & Syn-Eruptive Deformation and Seismicity at a Basaltic Caldera: Cascading Processes Leading to Eruption During the 2018 Eruption of Sierra Negra, Galapagos

Peter C. LaFemina*[1,2], Andrew F. Bell[3], Patricia M. Gregg[4], Zilin Song[5], Lillian Lucas[4], Mario Ruiz[6], Stephen Hernandez[6], Yen Joe Tan[5], Sofie Butcher[3], Matthew Head[4]

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The June 26 2018 eruption of Sierra Negra volcano, Galapagos Islands provides an opportunity to investigate volcano-tectonic interactions and magmatic processes in a basaltic caldera, including eruption triggering and caldera resurgence. Geodetic and seismic observations for the eruption cycle (2005 to 2018) provide new observations of dynamic caldera processes including: 1) the largest historically recorded pre-eruptive inflation (>6.5 m) and co-eruptive deflation (~8.5 m) without displacements on the ring fault; 2) correlation of uplift (inflation) and subsidence (deflation) rates with intra-caldera seismicity rates; 3) a reversal in slip polarity on the intra-caldera Trapdoor Fault system (TDF) from uplift during pre-eruptive to subsidence during co-eruptive events; 4) co-seismic displacements of >1.8 m due to a Mw5.4 earthquake on the TDF ~8 hours before eruption; and 5) net uplift (resurgence) of ~2.0 m of the Sinuous Ridge along the TDF. Here, we focus on geodetic and seismic observation of the ~9 hour period between the Mw5.4 TDF earthquake and eruption initiation. Repeating long period (LP) seismicity started ~3 hours and magma migration ~8 hours after the earthquake. The repeating LP earthquakes indicate failure and/or fluid processes along fault and fracture systems in regions of positive Coulomb Failure Stress change. Vertical and horizontal displacement of 2 cGNSS stations ~8 hours after the earthquake are best-fit by contemporaneous passage of a near vertical intrusion from a 2 km deep sill to eruptive fissures and deflation of the sill. These observations suggest a series of cascading process related to stress changes on the TDF.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

On-demand Sentinel-1 Interferogram Generation Service for Monitoring of Volcano Deformation

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Théo Mathurin[3], Nicolas Pascal[3], Roland Akiki[4], Jérémy Anger[4], Carlo de Franchis[4] [1]*Institut de physique du globe de Paris, Univ. Paris Cité, UMR 7154, Paris, F-75005, France;* [2]*CNRS, Laboratoire d'Optique Atmosphérique, UMR 8518, Lille, F-59000, France;* [3]*ICARE Data and Services Center, CNRS, CNES UMS 2877, Univ. Lille, Lille, F-59000, France;* [4]*Kayrros SAS, Paris, F-75009, France* Sentinel-1 interferograms today represent standard information to assess the extent and magnitude of ground deformation in volcanic areas. However, in spite of an open-access data distribution policy, rapid Sentinel-1 InSAR processing remains a challenge due to the large size of Interferometric Wide (IW) SAFE products. Institut de physique du globe de Paris (IPGP) and Université de Lille are developing an online open-access service for on-demand computation of Sentinel-1 interferograms focused on volcanic areas, accessible through a web application. InSAR calculation relies on the EOS-SAR Python library developed at Kayrros. EOS-SAR implements an accurate Sentinel-1 geometric model accounting for fine timing corrections, which allows to get native co-registration and stitching of bursts, resulting in a time series of well-aligned, geometrically consistent, Sentinel-1 bursts mosaics. The processing can be restricted to arbitrarily small AOIs, within a single or a few consecutive bursts or adjacent sub-swaths, which saves time, computing resources and storage space. The service leverages the Copernicus Data Space Ecosystem (CDSE) S3 object storage service for efficient data access.   Anticipated end-users of the service include volcano observatory teams, scientists and researchers from academia and students training in the field of volcanology and remote sensing.   The Sentinel-1 interferogram generation service for volcanic areas is developed as part of the "Volcano Space Observatory" platform, funded in the framework of the Horizon Europe, EOSC FAIR-EASE project (Grant 101058785), led by the French Research Infrastructure "Data Terra".

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Multiparameter insights into the months-long evolution of Mt. Etna discharge system prior to the December 2018 eruption

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Insight into the deep processes that set the conditions for the breakout of the December 2018 flank eruption of Mt. Etna is obtained through the joint analysis of gravity, ground deformation and soil CO_2 flux data. During June to September 2018, reduced permeability of the central discharge system favored flushing of CO_2 along peripheral paths and the development of a pistoning effect inducing cyclic mass changes in a magma reservoir at 2 - 3 km below the sea level. Successively, the permeability of the central conduit system increased, leading to a decrease in the soil CO_2 flux. Between early October and early November 2018, a gravity increase developed, indicating the addition of new mass at a depth of about 2 km below the sea level. Ground deformation data point to a volume change at deeper depth, suggesting that the shallower magma influx was accommodated by compression of the magma already residing in the reservoir. Since early November, further overpressurization could no more be buffered by the compressibility of the magma at 2 km b.s.l., due to the decrease in the volume fraction of exsolved gas, and was more effectively transmitted to the host rock, which enhanced transfer of gas and magma through the uppermost part of the discharge system, accompanied by growing unrest. We speculate that the magma accumulation during early October to early November pushed the plumbing system of Mt. Etna under disequilibrium conditions, ultimately favoring the emplacement of the dike which fed the December 2018 eruption.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Temporal Evolution of Etna's Eruptive Activity: Evidence from Geodetic and Petrological Data During the 2020-2022 Paroxysmal Activity

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Mount Etna experienced a remarkable eruptive cycle between 2020 and 2022. In December 2020 a paroxysmal period began, which intensified in February 2021 and lasted until the end of March (Sequence 1). After a short pause, a new paroxysmal period occurred from May 2021 to October 2021 (Sequence 2). The last paroxysms of this cycle were observed in February 2022. A total of 64 events occurred between December 2020 and February 2022. We investigated ground deformation patterns and magmatic processes associated with these paroxysmal sequences by integrating GNSS, InSAR, and petrological analysis. The eruptive sequences exhibited different characteristics in terms of magma supply rates, eruptive styles, and ground deformation patterns. Sequence 1 was characterized by higher magma supply rates, larger erupted volumes, progressive mixing with deeper magma, and pronounced deflation signal corresponding to larger paroxysms and dominant lava effusion. In contrast, Sequence 2 exhibited lower supply rates, more frequent but smaller paroxysms, a gradual trend toward primitive compositions and a lower-magnitude deformation signal associated with prevalent explosive activity. The time lapse between the sequences is interpreted to have prepared the conditions in the shallow reservoir for the shift from a prevalent effusive activity in Sequence 1 to explosive activity in Sequence 2. This period would introduce increased complexity, reflected not only in the potential magmatic processes during the second sequence, but also in the modeling of the associated deformation source. This analysis provides insights into how variations in magma storage conditions can influence both ground deformation patterns and eruptive styles.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Episodic oblique rifting events on the Reykjanes Peninsula, Iceland (2016–2024), imaged and modeled using InSAR and seismicity time series

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An earthquake swarm started in July 2017 marked the beginning of a new tectonic cycle on the Reykjanes Peninsula, followed by the onset of the Fagradalsfjall- Sundhnúkur eruptions in 2021. The mechanisms of awakening and the tectonic evolution of the plate boundary are, however, still poorly understood. To study the spatial and temporal evolution of the deformation, we integrated InSAR time series, GNSS data, and seismicity, discretizing the datasets in three key periods from 2017 to 2024 (pre-eruption, Fagradalsfjall, and Sundhnúkur eruption). These observations, together with source modeling of seismogenic faults, sills and dikes, reveal local and widespread deformation affecting the entire Peninsula already some years before the onset of the eruption sequence. The Fagradalsfjall dike, originating at a depth of around 10 km, and the three subsequent eruptions show a gradual growth of the dike in a northeasterly direction. Magma was then intruded into the Sundhnúkur rift zone (from Oct 2023) and caused more frequent eruption cycles with a marked decreasing intensity of the seismic activity for subsequent eruptions. The Sundhnúkur eruptive fissure, connected to the Svartsengi sill underwent 6 cycles of inflations-dike intrusions during the studied period. This work presents the first continuous InSAR timeseries covering the entire rifting episode that includes rapid deformation during earthquakes and eruptions for the Reykjanes Peninsula. It demonstrates the great potential of continuous geodetic and seismological observations for analyzing complex, long-term evolving volcanic-tectonic events.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

A parametric study on dike-induced deformation patterns at Mount Etna through analysis of a large set of 3D numerical simulations

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The study of surface deformation linked to dyke intrusions in active volcanoes is essential for understanding volcanic unrest and enhancing early warning systems. We present an analysis of a large set of 3D numerical simulations carried out using GALES, a multi-physics finite element code, to model elastostatic deformation due to dyke intrusions beneath Mount Etna. These simulations incorporate real topography and heterogeneous rock properties, ensuring an accurate representation of the geological conditions at the volcano. The simulations span a broad range of scenarios with varying intrusion depths, lengths, widths, and angles, aiming to provide insights into the relationship between magma dynamics and surface deformation. The resulting data will be used to explore key deformation characteristics, such as displacement patterns, strain distribution, and stress variations. These findings will contribute to a better understanding of the processes underlying volcanic unrest and may support the improvement of existing models for magma ascent and intrusion dynamics. Preliminary analysis of the simulation results will help identify potential correlations between different intrusion parameters and surface deformation patterns. The work also aims to establish a robust framework for interpreting real-time data from monitoring networks, which will be useful for future efforts in volcanic crisis management.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Subsidence at Barrancas Center: A New Deformation Anomaly in Laguna del Maule

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Cerro Barrancas (Neuquén, Argentina) is one of the longest-lived post-glacial eruptive centers in the Laguna del Maule Volcanic Complex (LdMVC). This eruptive centre includes a rhyolitic dome, obsidian and pyroclastic flows, younger than 14 ka. Using the Interferometric Synthetic Aperture Radar (InSAR) - Small Baseline Subset (SBAS) technique, a deformation pattern characterized by subsidence has been identified under the Cerro Barrancas. The registered maximum displacement velocity in the Line of Sight (LOS) reaches up to 1.65 cm/year, between October 2014 and July 2023. Although this subsidence pattern is located more than 12 km away from the main deformation center affecting the Laguna del Maule, it has not been reported in prior studies. The subsidence pattern coincides with the location and geometry of the Cerro Barrancas, and could be considered an independent deformation event from the historic main deformation registered at LdMVC. It could also be correlated to the gravity anomaly and seismic cluster analyzed in different works. Given the high-silica composition of the magmatic reservoir, this subsidence may reflect a contraction of the magmatic body responsible for the Cerro Barrancas. The findings highlight a localized deformation anomaly that contributes to our understanding of magmatic processes in the area and raises questions about the dynamics of the multivent volcanic systems. This study underscores the importance of further geophysical and geological investigations focused on the Cerro Barrancas to refine the interpretation and assess its potential volcanic hazard.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Stress interactions, faulting and sustainability at high-temperature geothermal systems: Implications from recent unrest in Svartsengi, SW-Iceland

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Geothermal production, including fluid extraction and re-injection, causes changes in crustal stresses and fluid pressures. These changes are well known to affect nearby seismicity and local fault movements, but can also affect dike propagation, dike arrest, and growth of magma chambers. The current unrest in Svartsengi, including several eruptions, high magma flow rates, and extensive surface faulting, occurs in an area where geothermal production in a high-temperature area has been ongoing since the 1970s with cumulative subsidence nearing 1/2 m. We calculate stress changes due to the long-term geothermal production, specifically focusing on normal stress changes affecting dike pathways. We find that contraction in the geothermal reservoir creates increased vertical tensional stresses below the reservoir, facilitating sill formation or magma accumulation, and thus capturing future heat source for the geothermal system in a sustainable way. The geothermal contraction also acts to increase horizontal tensional stress along the reservoir periphery while compressing the rocks above the reservoir, increasing probability of dikes reaching the surface along the sides of the geothermal system - i.e. towards the Sundhnúkar crater row. Plate boundary stresses, crustal structure, and magma pressures also play important roles in dike propagation and arrest. Our study showcases anthropogenic effects on magma propagation, and how geothermal energy production intrinsically has a self-sustainable component.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Ground Deformation Patterns in Tenerife (Canary Islands) Revealed by Time-Series Analysis of DInSAR SBAS and Independent Component Analysis of the 2004 and 2024 Unrest Episodes

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In 2004-2005, an anomalous seismic activity occurred in Tenerife, the island most populated of the Canary Archipelago. Since 2016, it exhibited again increased seismicity and heightened volcanic manifestations. Analysis of ground deformation using Envisat satellite data from 2003 to 2010, combined with the Independent Component Analysis (ICA) statistical tool, revealed a ground deformation on a few centimetres within the Teide-Pico Viejo volcanic complex. This deformation was modelled and attributed to an ellipsoidal deformation source beneath the Teide-Pico Viejo volcanoes, likely related to hydrothermal activity. In 2023-2025, the same volcanic area experienced a renewed ground deformation.To investigate the source of the observed anomalies in the Teide-Pico Viejo stratovolcano and compare its current behaviour with that observed in 2004-2005, we performed a DInSAR SBAS time-series analysis using data from the Sentinel-1 sensor. We selected ascending and descending orbits, sampling data from January to December 2024. The SBAS dataset quality was improved using detailed ICA decomposition to remove signal components unrelated to volcanic ground deformation. The component representing a clear ground deformation pattern was subsequently modelled to identify the position and geometry of the deformation source. We observe that ground deformation was concentrated in the stratovolcano area, with values approximating 3 cm/year of ground displacement. The ICA decomposition identified the deformation pattern responsible for the observed ground displacement in the Teide-Pico Viejo volcanic complex. Modelling the ICA pattern is a critical step in understanding the source of the observed behaviour and determining whether its origin is magmatic or hydrothermal.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.3: Movin' on up: Volcano geodesy applications and advances

Allocated presentation: Poster

Triggering of the 2024 Fernandina, Galapagos eruption by rainfall.

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It is well known that increasing precipitation related to global warming will lead to increases in volcanic hazards because of (i) explosive interactions between magma and external water at active lava domes, (ii) mudflows, and (iii) rainfall-triggered landslides. However, whether the precipitation infiltrated from the surface can impact the volcanic system at depth is less understood. The 2018 eruption and caldera collapse of Kilauea volcano, Hawaii, occurred after several months of anomalously high precipitation suggesting that it was facilitated by surface-induced pore-fluid pressure increases (Farquharson & Amelung, 2020), but this remains controversial. Here we present InSAR data of Fernandina volcano in the Galápagos Islands showing that the March 2024 eruption occurred without any precursory inflation, in contrast to previous eruptions that were preceded by several tens of centimeters of inflation in the years prior to eruptions. The 2024 eruption occurred during the rainy period, exacerbated by the 2023-2024 El Niño, suggesting that infiltrated rainfall could have been the trigger. We investigate eruption triggering by rainfall using satellite-measured precipitation data of the Global Precipitation Measurement mission and the Tropical Rainfall Measurement Mission since 2000 and gauge data from Santa Cruz Island since 1960. We show that 7 of the 16 Fernandina eruptions since 1960 occurred during the tertile of days with the highest 90-day cumulative precipitation, a factor of 1.3 more eruptions than expected by random, strongly indicating that Fernandina eruptions are impacted by precipitation.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

The continuous volcanic activity at Semeru volcano (Indonesia) from 2014 to 2023 investigated with remote sensing data (SAR, thermal and optical) and geodetic modelling.

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Semeru (Indonesia) is erupting since 2014, but its volcanic activity remains poorly constrained. Here we used a combination of different remote sensing data to improve the understanding of Semeru. Time series of deformation, obtained with Synthetic Aperture Radar Interferometry (InSAR) from Sentinel-1 data, show a constant subsidence of the SE flank occurred from 2014 to 2023. We modelled this deformation with a Boundary Element Method. Results show that the subsidence is related with a limited (~1×10^6 m^3) deflation of a shallow (~1 km from the surface) reservoir. Thermal data from MIROVA show peaks in the Volcanic Radiative Power and in the cumulative radiant energy (VRE) related with the main lava flow eruptions. By differencing high resolution (2m) Digital Elevation Models (DEM) derived from optical data (EarthDEMs), we found a bulk volume of ~46×10^6 m^3 erupted from 2014 to 2020. We used this volume to calibrate the VRE and to calculate the erupted volume directly from VRE for periods not covered by EarthDEM, allowing also the near-real-time estimation of the erupted volumes from MIROVA data. The discrepancy between the erupted volume and the modelled volume suggests that the shallow reservoir of Semeru is constantly fed by new magma that balances most of the erupted magma (or that directly fed the persistent eruption). This study highlights that the combination of different remote sensing data can be used to monitor, quantify, and interpret the volcanic activity in poorly monitored and studied volcanoes, highlighting the importance of remote sensing data for volcanology.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Using a Damage Approach to Model Pre-Eruptive Surface Displacements and Help Forecast Volcanic Eruptions

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Volcanic processes are various and controlled by a large number of parameters, which makes difficult complete studies of the volcano surface deformation and seismicity involving the coupled magma and edifice processes. One approach may be to study basaltic volcanoes, where magma is expected to be less compressible than in andesitic explosive volcanoes, and far less compressible than the volcanic edifice. It allows focusing research on the edifice constitutive laws, and their expression using geophysical observables. Volcano-tectonic seismicity may be used in modelling surface displacements before an eruption, using a damage approach and a simple magma pressurization model. It allows computing the time variations of the magma reservoir pressure and magma-edifice interaction power. When crack interaction reaches a sufficiently high level in the pressurized volcanic edifice (that is, when earthquake cumulative number exhibits some acceleration), the magma-edifice interaction power exhibits a maximum shortly before the eruption. At Piton de la Fournaise, the study of 24 summit-proximal eruptions recorded from 2003 to 2017 allows evidencing a relation between the times of this maximum and of the eruption. Applications will be presented to show how this knowledge could be used for forecasting these eruptions. Benefits of using INSAR with GPS data, and possible extension of this approach to andesitic explosive volcanoes will be discussed.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Probabilistic forecast of Vulcanian explosions at Sakurajima volcano using statistical features of ground deformation

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High-resolution ground deformation monitoring is useful for forecasting volcanic explosions because pre-eruptive deformation due to magma intrusion has been observed at many volcanoes. However, it is still challenging to precisely predict the timing and size of the imminent explosions. Therefore, the probabilistic approach effectively forecasts explosions and quantifies the risk of volcanic hazards considering various uncertainties. We focused on the short-term forecast of Vulcanian explosions at Sakurajima volcano, Japan. The volcanic activity of the Sakurajima volcano is characterized by frequent Vulcanian explosions, accompanied by inflation-deflation patterns of extensometer records. We made a large database of the volume change and durations of precursory ground inflation related to explosions at Showa and Minami-dake craters in 2009–2020. By using this database, optimal stochastic models for their distributions were estimated. As a result, the log-logistic distribution is more appropriate than Weibull and exponential distributions. The model parameters of the log-logistic distribution temporally fluctuated, reflecting volcanic activity, especially in increasing the magma supply from a deep region. We also proposed a methodology to calculate the probabilities of the likely timing and size of the subsequent explosion using strain monitoring and the estimated stochastic model. Although validation with real cases and some refinements are still needed before a forecast system can be practically implemented, the basic concepts we propose would also pave the way to the short-term forecasts of other volcanoes.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Using remote sensing techniques to analyze physical dynamics and paroxysmal precursors during the 2019–2020 and 2023 eruptions at Shishaldin Volcano, Alaska

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Ash-producing volcanic eruptions pose a risk to nearby towns and a widespread risk to aviation. During persistent eruptions, mafic stratovolcanoes can produce paroxysms, which are sudden plume-producing events that are often preceded by strombolian or lava fountaining activity. In 2019-2020 Shishaldin Volcano in Alaska, USA erupted, producing three different paroxysms that were characterized by sustained strombolian activity and lava effusion that preceded large ash plumes. Shishaldin erupted again in 2023 with 13 paroxysms, which unlike 2020, were not preceded by lava flows. To understand the differences between these two eruptions, their individual paroxysms, and paroxysmal precursors, we used GOES (Geostationary Operational Environmental Satellite) spectral radiance data to quantitatively characterize eruptive style with volcanic radiative power (VRP), plume heights, and plume spectral characteristics, and compared this to seismicity (e.g., reduced displacement) in the time before and during all paroxysmal events. We then compared event characteristics such as plume height, plume duration, maximum VRP, etc. and ran correlation statistics against thermal and seismic precursor signals. We saw that reduced displacement peaks and plume height peaks were often not correlated, with offsets greater than ten minutes. We also found that seismic run-up time and the time between plume onset and plume peak are positively correlated, indicating that the longer the seismic run-up, the longer time before the plume peaks. Overall, the 2019–2020 and 2023 precursory and paroxysmal events are not distinguishable within our measurements , but the relationships between precursor durations and paroxysm timing are consistent, informing potential future eruption forecasting.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Periodic dike intrusions in Kīlauea's middle East Rift Zone continue post-2018

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Intrusions and eruptions on segments of Kīlauea's East Rift Zone (ERZ) demonstrate periodic recurrence times correlating with the sliding velocity along the adjacent flank décollement (Montgomery-Brown and Miklius, 2021). Persistent segmentation and regular recurrence intervals were discovered only by including both intrusions and eruptions. Middle ERZ segments demonstrate 14-year recurrence intervals with adjacent flank décollement slip rates of ~0.1 m/yr, whereas upper ERZ segments are less regular, but average ~8 years with higher adjacent flank slip rates of ~0.15 m/yr. Lower ERZ periodicity is more difficult to constrain with substantially fewer observed events, longer interevent times, and much slower adjacent flank slip rates (<0.01 m/yr); however, historic records and previous eruptions indicate a recurrence interval of about 50 years (Denlinger and Morgan, 2014). The regular recurrence intervals were initially thought to occur only during periods of open-system effusive eruptions, like the extended 35-year eruption of Pu'u'ō'ō. The plumbing system was disrupted by the 2018 events – including dike intrusion, eruption, and M6.9 earthquake – that caused drastic changes to Kīlauea's behavior (e.g., periodic decollement slow slip events have not resumed, but flank slip velocities remain elevated). In September 2024, a middle ERZ dike erupted in Nāpau crater in the same region as previous events (1997 and 2011), and on-schedule for the 14-year recurrence, despite large-scale disruptions in 2018. Persistent, periodic recurrence times of intrusions in Kīlauea's upper and middle ERZ segments through the 2018 events provide further evidence of the tight coupling between magma supply and flank deformation at Kīlauea.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Seasonal Control on Phreatic Activity of the Crater Lake of Copahue Volcano During the 2018-2022 Eruptive Cycle

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The last eruptive cycle of Copahue volcano, located on the Argentina and Chile border, began in 2012 and continues upto the present. One of the characteristics of this volcano is the hot acidic lake located in its crater, which has undergone various changes in the past 20 years, as a result of different eruptive phases. In particular, between 2018 and 2022, changes in the crater lake level were associated with periods of increased surface activity, characterized by phreatic eruptions and SO_2 emissions into the atmosphere. We carried out a multiparametric analysis, finding correlations between the crater lake hydric balance with annual seasonal changes, gas and ash emissions, and temporal variations in the tremor seismic signal. These correlations allowed us to infer that during the cold months, the ambient temperature prevents the thaw that feeds the shallow hydrothermal system, favoring evaporation and reduction of the crater lake volume. Consequently, less efficient heat dissipation and scrubbing processes favored seal vent, likely dominated by liquid sulfur and hydrothermal precipitation in the shallow conduits. Eventually, the gas overpressure in the conduits reaches a critical state, which is manifested through increased tremor activity. When the seal is ruptured, an abrupt drop in the seismological signal is observed. This activity is followed by phreatic eruptions or large SO_2 releases into the atmosphere. This crater lake behavior has occurred annually from 2018 to 2022, evidencing a seasonal control on shallow hydrothermal system and the phreatic activity of Copahue volcano.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Progress in short-term eruption forecasts by the USGS-USAID Volcano Disaster Assistance Program (VDAP)

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As part of VDAP's program to support volcano observatories, we are often asked to assist our international counterparts with short-term eruption forecasts. Our preferred method for forecasts is an event tree, an excellent means to assess relative probabilities for a suite of potential eruptive and non-eruptive outcomes. We perform quarterly exercises to quantify probabilities of eruptions at restless volcanoes worldwide. The exercises expose weaknesses in our methods and gaps in our background data, while allowing us to recognize ways to avoid cognitive biases in how we design surveys and assign probabilities. We are actively undertaking several projects to support short-term forecasts. With USAID funds, we are expanding our partnership with the Smithsonian Global Volcanism Program to include a Daily Volcanic Activity Report (DVAR), which will be based on volcano observatory reports. Additionally, the data will populate VDAP's Eruption Chronology (Echron) database and support WOVOdat. The DVAR can be facilitated by improved reporting protocols, standardized data formats, and templates for use by the global volcano observatory community. Reports from VAACs and satellite observations will enrich the pool of data used to optimize forecasts. In addition, VDAP seismologists are working to develop methods and software to better interpret volcanic earthquakes and swarms, and to track variations in earthquake families. We use infrasound to locate eruptions sources, and we explore potential correlations between eruptions and regional tectonic earthquakes. We are excited by how these different threads can help the global community improve tools to forecast behavior at threatening volcanoes.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

The July, 2024 Hydrothermal Explosion at Black Diamond Pool in Yellowstone National Park: The Scientific Response and What We've Learned

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On July 23, 2024, one of the largest historical hydrothermal explosions in Yellowstone National Park occurred at Black Diamond Pool in the Biscuit Basin hydrothermal area. The explosion sent a plume of rock, steam, liquid water, and mud 100-200 meters into the air with many visitors bearing witness and capturing dramatic videos. The boardwalk next to Black Diamond Pool was heavily damaged by the ejected mud and rocks, yet luckily nobody was injured. The closest permanent seismic station to the explosion was 4 km away and did not record any definitive signal. The visibility of the event and accessibility of the location motivated a robust response with the goals of a better understanding of this hazard, as well as the potential to inform ongoing efforts towards forecasting future hydrothermal explosions. Immediately after the event, scientists collected continuous temperature data of the thermal spring and the surrounding ground, mapped the ballistic debris field and water surge areas, deployed 35 geophones to collect continuous seismic data around Biscuit Basin, installed a 4-microphone infrasound array and acquired thermal and optical images from an Uncrewed Aircraft System. Here we present observations and preliminary analyses which suggest that the 2024 Biscuit Basin explosion was probably caused by self-sealing of the shallow hydrothermal system, causing pressure to build until it exceeded the strength of the overlying rock. Post-explosion monitoring data show that dozens of smaller explosions have occurred with varying sizes and amounts of ejected rocks and water, demonstrating a continuing hazard.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Optimising timescales for machine learning-based eruption forecasting: Insights from Miyakejima Volcano, Japan

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Volcanic eruption forecasting has the potential to save lives and contribute to community preparedness in volcanic areas. One of the most important aspects to forecast is the timing of eruption onset on short-term (days to months) timescales. This work uses timescales to optimise machine-learning models that forecast eruption onsets from monitoring data. For this, we evaluate forecasting model performance while adjusting the length of two key windows: the "data window" (period of data collection, used by forecasting models to detect signs of impending eruptions) and "forecasting window" (period over which models estimate eruption likelihood) – each between 3 and 90 days – to understand the influence of timescale selection on short-term eruption onset forecasting. We applied this method on processed seismic data for Miyakejima volcano (Japan). Preliminary tests on individual eruptions revealed interesting patterns, including an inverse relationship between optimal data and forecasting window lengths (i.e., longer forecasting windows must pair with smaller data windows, and vice versa, to improve performance) for models tuned to the January 2008 eruption; and distinct optimal window combinations for other data-/eruption-cases. These results (1) suggest that model performances may vary with considered timescales, underscoring the importance of conscious data- and forecasting-window choices in future work, and (2) open up possibilities of earlier notice for imminent eruptions and enhancing forecasts at Miyakejima and beyond. We are currently retuning the models to forecast multiple eruptions. Further research will examine factors that contribute to the success of particular data-/forecasting-window combinations, and their potential to generalise across volcanoes.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Lessons learned from near real-time monitoring of volcanic unrest and dike propagation/eruption forecasting in Iceland

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In October 2023, rapid inflation commenced in the Svartsengi volcanic system which culminated in a very large dike intrusion on the 10 November 2023. The inflation resumed soon after the event before triggering a new dike intrusion, this time associated with an eruption, in December 2023. This pattern started again and prompted the creation of a series of tools to be able to i) monitor the magma inflow within the reservoir beneath Svartsengi, ii) forecast the timing of the next dike intrusion based on the magma recharge rate and volume, iii) track dike intrusions in real-time as they propagate and estimate the potential location of eruptive fissures and iv) predict a likely end of the eruptive episodes. The local continuous GNSS network is providing the input data for the geodetic inversions/modeling required by these tools. All the tools are fully automated and are run on a daily basis (i, ii, iv) or a 5-min basis (iii). The results have proven to be very useful for the monitoring of the volcanic system and forecasting future events, despite the associated uncertainties. They are now routinely used, among other tools, by the monitoring team at the Icelandic Meteorological Office to inform the Department of Civil Protection and Emergency Management, relevant stakeholders and the general public on changes in activity and the timing of the increased likelihood of diking events/eruptions. Some of these monitoring tools have also been expanded to include other volcanoes, also in state of unrest in Iceland, like Askja and Bárðarbunga.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Temporal Evolution of Crustal Stress and Seismicity at Volcanoes During Periods of Unrest

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Eruptions that occur at volcanoes after periods of quiescence are difficult to forecast. Pathways that connect the source to the surface may have become sealed. The pressurisation of the source leads to the deformation of the crust. Initially the crust deforms elastically, strain is accommodated via ground movement and elastic strain energy is stored to the crust. Then, the deformation transitions to inelastic where strain is accommodated via brittle failure (volcano-tectonic event), and elastic strain energy is transferred from the crust. We present a novel method to estimate the temporal evolution of elastic strain energy and bulk stress during periods of unrest. We consider the transfer of energy using measurements of surface deformation and seismic activity. We evaluate the temporal evolution of crustal bulk stress and investigate the progression of deformation in the crust. We apply our method to the unrest at the Campi Flegrei caldera, Italy from 2011-2024. Our calculations reveal that the bulk stress follows a characteristic progression, in which the stress initially increases linearly with time prior to the onset of significant seismicity, consistent with elastic deformation. We then observe a transition to inelastic deformation, when rate of elastic strain energy lost via fracturing increases and eventually exceeds the rate of elastic strain energy transferred to the crust. This results in a decrease in the bulk stress stored in the crust with time. Comparison with laboratory experiments show the behaviour is consistent with bulk failure in extension and the potential formation of new pathways in the crust.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Exploring multiparametric data analyses to study volcanic activity at Stromboli from 2016 to 2024

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Eruptive activity at Stromboli mostly features mild, persistent, namely Strombolian, explosive activity from summit craters. The energy associated with the explosions changes through time, and periodically leads to stronger events usually classified as major explosions and, occasionally, paroxysms, such as those that occurred in 2019 and 2024. This eruptive activity generates a wide variety of geochemical and geophysical signals, associated with the ascent and interaction of gas and magma along the conduit. We performed a joint analysis of seismic, geochemical, meteorological, and sea-level gauges data from 2016 to 2024 to identify and characterize patterns in the time series, especially during more energetic episodes: (i) we implemented algorithms for the automatic detection of events with similar waveform features; (ii) we analyzed the effect of external perturbations as oceanic microtremor and tides on continuous and discrete amplitude-based measurements; (iii) we studied the temporal and size distribution of event occurrences, and use this information to assess likely trends in eruptive behavior, (iv) we used noise cross-correlations to compute seismic velocity variations of the shallow crust. The joint analysis of multi-parametric measurements provide interesting insights in the temporal evolution of the eruptive activity at Stromboli; for example, correlated changes in the pattern at which events occur in time, patterns in the distribution of extreme-amplitude events, and evidence of a decrease in seismic velocity, seem to be phenomena occurring before paroxysmal eruptions. Further analyses based on pattern recognition techniques can provide new insights on the volcanic processes generating these observations

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Identifying dike propagation patterns at Mount Etna through forward-modelling and AI-powered ground deformation inversions

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Surface deformation at active volcanoes is caused by subsurface magma dynamics, which induces pressure variations within magma sources. These variations cause stress changes in surrounding rocks, propagating deformation signals to the surface, where monitoring networks detect them. To aid in near-real-time analysis of these signals, we are developing a digital twin for dyke propagation-induced deformation at Mount Etna, combining 3D numerical simulations with artificial intelligence (AI). We simulated 10^7 realizations of dike intrusions underneath Mount Etna using the open-source multi-physics finite element software GALES on Leonardo HPC (CINECA), solving for the elastostatics induced by overpressurized dykes within a spectrum of dyke geometries mimicking the observed variability at Mount Etna. The 3D computational domain includes the latest DEM topography and heterogeneous rock properties from seismic tomography surveys. The results provide a comprehensive picture of input-output (source - deformation) relationships used to train an AI that reconstructs probability distributions for source parameters from GNSS deformation datasets. Feeding the AI with near-real-time data provides a probabilistic evolution of the source. The inversion procedure will be triggered by another AI module that scans multi-parametric monitoring data streams at Etna Volcano Observatory to identify unrest conditions. This methodology allows to better constrain dike intrusion parameters and to follow the evolution of unrest as deformation patterns evolve. All software will be shared as an open-source tool, providing a valuable resource for civil protection authorities and offering the potential for replication on other volcanoes, representing a significant step forward in volcanic crisis management and monitoring.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Talk

Using Low-frequency DAS Signals for Early Warning During the Sundhnúksgígur, Iceland, Eruptions in 2024 Authors/Affiliations

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The Reykjanes peninsula, Iceland, has been experiencing unrest since 2019. Since Nov 2023 the activity has been focused along the fissure swarm of Sundhnúksgígur, with 10 intrusive events of which 7 were eruptive. The eruptive fissure is located just north of the town of Grindavík, and about 2 km away from the Svartsengi geothermal power plant and the Blue Lagoon spa, a major tourist attraction. Evacuations, based on increased seismicity at the center of the activity, together with pressure signals on a borehole sensor within the geothermal field, have been issued as little as 30 minutes before the eruption. From Nov 2023-Nov 2024 a DAS interrogator was running in the peninsula, converting a 100-km-long telecommunication fiber cable crossing Grindavík into a dense array with 10,000 strain-rate sensors. Clear low-frequency signals are visible on the fiber more than 30 minutes before each eruption. We developed a warning system using the amplitude of low-frequency strain rate (LFDAS). The alert has been running at the Icelandic Meteorological Office (IMO) since April 28th, 2024. The strain rate observed on the fiber, together with seismicity and pressure changes on a borehole pressure sensor, have caused the IMO to issue and to refrain from issuing warnings, demonstrating the immediate utility of the LFDAS observations. Furthermore, the similarity of strain signal in the events was used to predict the timing of the August 2024 eruption, to within 10 minutes. In this presentation, we describe the methodology and results from the LFDAS monitoring of the ongoing Sundhnúksgígur sequence.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

A next generation, near-real-time volcanic eruption monitoring algorithm for use with both MODIS Aqua/Terra and SNPP VIIRS, providing continuity with the MODIS/EOS era MODVOLC system

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The MODVOLC system has provided 24 years of global data regarding volcanic thermal unrest at near daily temporal frequency (https://modis.higp.hawaii.edu). With the EOS era coming to an end, we have developed a new approach which will be applied retroactively to the Terra/Aqua MODIS archive, as well as for the near-real-time analysis of data from current and future VIIRS sensors. The new approach has taken decadal, global archives of Terra-MODIS, Aqua-MODIS and VIIRS data, to determine how 'hot' each km^2 of Earth's land surface has been in the absence of a volcanic heat source. This improved algorithm will work simply by comparing the 4μm radiance for each pixel in a 'new' MODIS/VIIRS image with its geographic counterpart in the historic reference image. We will present results describing how the new generation algorithm was developed, as well as its performance relative to i) the existing MODVOLC algorithm, and ii) the MODIS Fire product for both day and night images. The new algorithm provides improved detection capabilities of as much as 200% (in terms of number of valid detections). Importantly, the computational complexity of the new algorithm is even simpler than the MODVOLC algorithm, involving a single floating-point comparison operation per pixel. This characteristic has an important implication for future detection algorithms for analysis of high spatial resolution thermal data, for which the order of magnitude increase in the number of pixels to be analyzed requires a computationally simple algorithm, especially if processing is to occur on-board the spacecraft for real-time product delivery.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Hidden Markov Random Fields as scaffolding around Indigenous Knowledge at Ruapehu volcano

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Accurate eruption forecasts are vital for emergency management decisions. Volcanic eruption forecasting is intrinsically uncertain, with uncertainty stemming from the incomplete knowledge of system dynamics through to incomplete and temporally biased eruption records. This lack of data severely hinders business as usual forecasting methods and eruption forecasting continues to show room for improvement. Here, a conceptual solution is presented for Ruapehu volcano, coupling the long-lived experiential knowledge of Māori iwi and hapū of the region to instrumental monitoring records using flexible and adaptive statistical models. This approach avoids over smoothing methods and instead retains all characteristics and context of this multi-dimensional qualitative and quantitative information. We describe the opportunities and pitfalls that we have encountered so far during the integration of such wildly diverse data and knowledge into Hidden Markov Random Fields (HMRFs), and discuss the less esoteric issues of reliability, noise-to-signal ratios, environmental-interference, and how we might move towards causal representation learning in volcanology.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Forecasting the position and timing of eruptive vents using a particle filter method.

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To assess volcanic risks, we need to determine as early as possible if, where and when the magma propagating from the storage zone will reach the surface. Data assimilation is an efficient way of combining a dynamic magma propagation model with recorded geophysical observations. Here we develop a particle filter method in the two-dimensional case of magma propagation beneath a caldera in an extensional stress field. The dynamical model provides the position, size and geometry of the magma intrusion from a set vector of 7 parameters : the initial magma position at depth, its viscosity and driving pressure, the volume of magma injected, the crustal rigidity and the local stress field. Surface displacements induced are estimated using the Okada dislocation model. The Particle Filter Method, based on the Monte Carlo principle, aims to provide an increasingly accurate estimate of the model state throughout the assimilation cycles (forecast–analysis). At the forecast step, the dynamical model is run forward for a large number of model state vectors (namely particles). At the analysis step the likelihood of the particles is calculated by comparing the theoretical displacements to the observed displacements. Then, particles with higher likelihood are retained, while the others are resampled by the Stochastic Universal Sampling method. The assimilation strategy has first been tested with synthetic data. 100 particles are generally enough to accurately forecast the location and timing of arrival. The time between assimilation steps must remain less than 1% of the total magma propagation time to ensure correct prediction.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Resolving traction changes on fractures in a 3D heterogeneous crust using fictitious domains

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To track magma transport and to understand the seismic cycle, deformation data are analyzed relying on forward deformation models combined with inversions. When the geometry of the fracture is known, it is discretized with dislocations, and a least square cost function subject to a regularization constraint on the dislocation amplitudes is minimized. Most of the times, the dislocation solutions assume the earth is an elastic, homogeneous half-space, which may lead to inaccurate inversion results. To address this issue and to invert for a more physical quantity (stress vector rather than dislocation), we present a new method based on a fictitious domain approach inspired by extended finite element methods developed for cracks that do not follow volume meshes. The cost function involves the misfit between the solution of the physical problem and the observed data together with regularization terms. An algorithm is presented which relies on the forward and the adjoint problem. Synthetic tests, relying on the determination of the regularization parameters by L-curves, show that an initial solution is reliably determined. The method is then reformulated to be applied to InSAR data, which correspond to an incomplete knowledge of the displacement field. Synthetic tests demonstrate the efficiency and robustness of the method for one to four Line-of-Sight observations, with missing data and variable noise. The method was then applied to the May 2016 Piton de la Fournaise intrusion, and we found that our results are consistent with a previous analysis reying on a different approach.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Strain tomography of magmatic systems

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Sylvain Barbot[2] [1]*School of Earth sciences, University of Bristol, UK.* [2]*University of Southern California, US.* Understanding volcanic chamber conditions using mechanical models is important for forecasting eruptions. Traditionally, we rely on kinematic models to invert surface deformation data at a given time to estimate magma chamber conditions such as size, shape, volume or pressure changes. However, it is well established that the rheology of the rock surrounding magma chambers alters the deformation signal over time, making static kinematic models unreliable for accurately estimating pressure/volume changes. Here we address the challenge of inferring the rheology of the crust surrounding magma chambers to improve the reliability of deformation-based estimates of chamber conditions. We employ strain tomography, originally designed to model asthenospheric flow following earthquakes. This approach uses a suite of solutions for the displacements and stress around distributed anelastic deformation which are superimposed to estimate the surface deformation associated with arbitrary distributions of strain. This approach allows us to invert ground deformation signals to estimate the rheology of the crust without assuming a fixed source geometry. We benchmark our new method against a synthetic test case: a 2D analytical viscoelastic shell model. We demonstrate that strain distributions inverted from snapshots of deformation can estimate the rheology of the crust in our synthetic test within an order of magnitude. Thus, we infer that inverting for the strain distributions using satellite deformation datasets from actively deforming volcanoes will provide critical insights into the mechanical properties of the rock mass. These novel methods bridge a gap between mechanical models and readily observed signals, advancing our forecasts of temporal magmatic processes.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

The first instrumentally detected hydrothermal explosion in Yellowstone National Park

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Hydrothermal explosions are an underappreciated hazard in Yellowstone National Park, and their impact and importance were demonstrated by the well-observed event on July 23, 2024, at Biscuit Basin. To monitor hydrothermal activity, the Yellowstone Volcano Observatory is installing monitoring stations in geyser basins, with sensors including broadband seismic, GNSS, meteorological, and infrasound. The first such station was installed in Norris Geyser Basin in September 2023. Infrasound array data from that site recorded an impulsive signal coming from the northeast on April 15 at 20:56 UTC (14:56 local time). Data from nearby broadband seismometers are indicative of a ground-coupled airwave, suggesting that a small explosion had occurred. High-resolution satellite imagery from the explosion source direction indicated a drop in the level of water in hot springs between April 2 and 21, and field observations in May identified the presence of newly disrupted ground, including a crater 3 meters in diameter surrounded by clasts of silica sinter. Recognition of the explosion confirms the utility of hydrothermal monitoring and argues for expansion of the network at Norris Geyser Basin and in other thermal areas to better characterize the process, assess any precursors that might aid with forecasting, and detect future explosions to establish their frequency and patterns of occurrence. The July 23, 2024, explosion at Biscuit Basin was only weakly detected in retrospect at a broadband seismic station a few kilometers away, emphasizing the importance of both local infrasound and seismic monitoring.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Study of the explosive eruption jets with the experimental and theoretical approaches

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Often the seismic waves from an explosive eruption are generated by a nearly vertical single force F_s which is usually interpreted as the reaction force F due to the ejection of materials during an eruption. Analysing this single force F_s may allow to evaluate the mass discharge rate $\dot{m}$ and the style of the eruption. In this work we started with investigating the relationship between the mass discharge rate and reaction force using an experimental setup to measure the single force F_s during water ejection from a plastic bottle. A series of experiments using different initial pressure and varying the cross-sectional area of the jet was performed. As a result, we report on the reaction force $F = \frac{3}{2}\dot{m}v$, although traditionally the reaction force F has been considered as $\dot{m}v$. The next step of this study was calculating synthetic waveforms and their comparison with the real seismograms recorded during 2022 Hunga Tonga–Hunga Haʻapai eruption. The far-field seismic wavefield can be expressed as a convolution of the single force $F_s(t)$ with the Green's function. The last one was calculated as a response of a homogeneous elastic half-space to a vertical point force applied to the surface. As for the single force $F_s(t)$, we upscaled the time series from the experiments to the duration of a real eruption. Finally, the computation result was compared with the one obtained using the single force $F_s(t)$ in the general form of a triangular pulse.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Bridging the Gap Between Magma Conduit Models and Near-Field Ground Deformation Observations

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Ground deformation at volcanoes offers critical insights into magma plumbing systems across diverse temporal and spatial scales. Understanding of ascent dynamics within volcanic conduits are crucial for utilising near-field ground deformation as a monitoring tool. This study uses finite-element modelling to simulate magma ascent, examining how model parameters and formulation influence pressure and shear stress along conduit walls. Key factors include conduit geometry, boundary conditions at top and bottom of conduit, magma composition, crystallisation, gas exsolution, and plug formation. Our models clarify how magma conduit conditions, such as pre-explosive pressurisation or magmatic plug formation, can be detected by geodetic methods and define the requirements for effective monitoring. Focusing on magma ascent in silicic volcanoes during lava dome-building eruptions, we explore how ground deformation, combined with seismicity and lava dome growth data, reveals the state of the magma conduit. We also assess the potential of high-resolution InSAR to complement ground-based geodetic techniques like tiltmeters and GPS. Finally, we address the challenges of implementing these methods for routine monitoring, aiming to improve volcanic hazard assessments.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Integration of satellite and ground-based thermal sensor surveys to constrain heat fluxes at hydrothermal systems: experiences from Poás and Nisyros

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At active volcanic hydrothermal systems, enhanced heat flow results in surface heating and elevated heat flux densities. We consider heat transfer models for: (1) “dry” systems with soil heating and fumarolic activity, and (2) “wet” systems, i.e., a crater flooded with an acidic lake. Our aim is to collate and review methods to calculate heat flux, while assessing the role of external atmospheric processes. To do this, we completed thermal mapping and collected meteorological data in June 2022 at Nisyros (Greece) and in February 2002 at Poás (Costa Rica). Measurements coincided with a thermal infrared satellite sensor overpass. At both systems, the low magnitude of the thermal anomaly means that atmospheric factors, in particular vapor pressure, drive high degrees of variation in heat flux during a diurnal cycle. These variations overprint the volcanic heat flux component. To characterize heat fluxes at a hydrothermal system, it is best to integrate through a whole diurnal cycle. At Nisyros and Poás, agreement between ground and satellite-based values of heat flux gives us confidence in our calculations. Heat fluxes were relatively low, 34.2±9.1 MW and 51.7±10.5 MW respectively, revealing a baseline state of activity. Our intention is that heat flux calculation methodologies detailed and validated here can be used at other similar systems. The key is to adequately account for atmospheric parameters in the thermal boundary layer, i.e. within 10 cm of the surface. This allows robust and comparable heat flux inventories to be applied to better understand activity at hydrothermal systems.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Constraints on magma ascent to eruption from patterns of unrest

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Episodes of unrest at subduction-zone volcanoes show repeatable variations with time in rates of volcano-tectonic (VT) seismicity. Two common sequences are distinguished by whether they culminate in an increasing or decreasing VT event rate. Both have been illustrated at Soufriere Hills on Montserrat. Before its eruption in 1995, after three centuries in repose, VT rates changed from an exponential increase to a constant value and then to a hyperbolic increase. In contrast, during a non-eruptive VT sequence in 1966, the opening exponential and constant rates were followed by an inverse-time decay. The hyperbolic increase is consistent with the growth and linkage of fractures to allow magma ascent. It is thus tempting to infer that a final decay indicates conditions unfavourable to eruption. Such an inference, however, would be an over-generalisation. At Mount St Helens (USA) in 1980 and at Agung (Indonesia) in 2017, eruptions occurred at the end of declining VT event rates. Independent studies suggest that the Mount St Helens eruption was promoted by the collapse of its northern flank under the weight of shallow injections of magma, whereas the Agung eruption followed new magma entering previously opened fractures. Apparently, therefore, the initial exponential and constant-rate trends coincide with fractures being opened wide enough to allow magma to reach shallow depths, but not to erupt without an additional factor coming into play (*e.g.*, fracture linkage, edifice instability or injection of new magma). Incorporating such factors is thus important for enhancing forecasts and scenario planning during an emergency.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

The new Daily Volcanic Activity Report: using daily volcanic event data for eruption forecasting

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The new global Daily Volcanic Activity Report (DVAR) extracts, archives, visualizes, and summarizes multidisciplinary observational and volcano monitoring data from numerous primary sources on a near-daily basis. This collation and distribution of global volcanic activity data, presented in the DVAR as graphical plots and short narratives on the Smithsonian Institution's Global Volcanism Program (GVP) website, aims to provide timely updates for situational awareness during volcanic unrest and crises and archives this information in a database. The project is a joint effort between the USAID-US Geological Survey (USGS) Volcano Disaster Assistance Program (VDAP) and the GVP, with support from the US Agency for International Development's Bureau for Humanitarian Assistance (USAID/BHA). The DVAR supports VDAP's global Eruption Chronology (Echron) database, GVP's Volcanoes of the World (VOTW) database, and the World Organization of Volcano Observatories (WOVOdat) database by recording daily volcanic event data (e.g., explosions, pyroclastic flows, earthquakes, and alert level changes) and properties. Volcanic event chronologies recorded in the DVAR can be used for eruption forecasting in multiple ways. A detailed chronology of unrest and eruptive events at a volcano in crisis gives a holistic view of all activity to date for interdisciplinary discussions, visualizations, and forecasts of potential outcomes. Global chronology information, obtained from the DVAR and coupled with other global databases, can provide the data needed for statistical analysis of analog volcanoes, unrest sequences, and eruptions. This presentation introduces the DVAR and explores the uses of daily global data for forecasting, including short-term forecasting and forecasting eruption transitions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Resistivity: a new volcano monitoring tool?

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Geo-electric methods have become increasingly important in the characterization of volcanic systems. Due to their sensitivity to temperature, saturation, and certain clays and minerals, they have applications in reservoir characterization and edifice stability but studies remain static. With the ERupT project, we assess the suitability of ERT and IP to visualize the dynamics in volcanic hydrothermal systems, aiming long-term to improve hazard assessment relating to hydrothermal eruptions. A monitoring profile was installed on the Reykjanes Geothermal field (Iceland) where ERT and IP are measured daily since 23/10/2022 (still ongoing with a few interruptions). The 2021 eruption at Fagradalsfjall marked a new age of volcanism in the Reykjanes peninsula. Since the start of our campaign, Fagradalsfjall erupted on July 10th, 2023, after that the Svartsengi system activated and has been periodically erupting since December 18th, 2023. The eruption sites are located at respectively 10 and 25 km from the fieldsite. Although the ERT system is located at a considerable distance from both eruption sites and the investigation depth is shallow (down to ~50m), we observed signals possibly related to both eruptions and the accompanying unrest, on top of more local signals (e.g., meteorological). Prior to the 2023 eruptions of Fagradalsfjall and Svartsengi, our system recorded an increase in resistance (<100%) followed by an earthquake swarm and later the eruptions. We hypothesize that the ERT signal is related to magma degassing during uprise. This is the first study using ERT as a volcano monitoring tool, showing great potential for future monitoring.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Lagrangian volcanic ash transport from sea surface to seafloor following the January 15, 2022, eruption of Hunga volcano.

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The January 15, 2022, eruption of Hunga volcano produced an ashfall isopach deposit ~450 km in diameter, extending >200 km from source. Utilizing a predicted isopach at the sea surface and a 3D lagrangian particle tracking model, we predict the dispersion of 2022 Hunga volcano ashfall from sea surface to seafloor. Seafloor cores containing ashfall facies from the eruption are used as control points within the model. Previous works support suggest that high ash concentrations remain in the top 20 m of the water column remains high for ~approximately 10 ten days after the eruption. Based on this observation, we hypothesize that a significant portion of Hunga's ashfall did not rapidly settle through the water column and subsequently was potentially displaced via ocean currents. This would result in a vastly different seafloor isopach to its corresponding sea surface isopach. To test this hypothesis, we use a predicted isopach at the sea surface and a 3D Lagrangian particle tracking model to predict the dispersion of 2022 Hunga volcano ashfall from the sea surface to the seafloor. Seafloor cores containing ashfall facies from the eruption are used as control points within the model. Investigating submarine particle transport following volcanic eruptions will elucidate the transport potential of volcanic ash in the submarine realm. Such knowledge would greatly benefit interdisplinary studies on the effect of volcanic ash in marine ecosystems.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Volcano monitoring challenges in an active Quaternary monogenetic volcanic province in western Saudi Arabia

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Al-Madinah Al-Munawwarah is a city with approximately 1.5 million residents, which doubles during major pilgrimage periods. The city is located in the northern part of the Arabian Shield and is surrounded by three active, low-recurrence Quaternary monogenetic volcanic fields. To the north of the city lies Harrat Khaybar, a lava-dominated volcanic field. Harrat Al-Madina, where the city is situated, is part of the extensive northern tip of Harrat Rahat. On the western side is Harrat Lunayyir, which experienced volcano-seismic unrest in 2009 due to a failed eruption. These volcanic eruptions are among the most significant monogenetic volcanic field formations in the world. Harrat al-Madinah, located south of the city, is one of the most volcanically active areas in the region. Geological mapping has identified more than thirteen volcanic eruptions over the past five thousand years, equating to a major lava-emitting volcanic eruption every four hundred years on average. The most recent volcanic eruption in the Arabian Peninsula occurred in the year 654 AH (1256 CE), resulting in a 2.3 km-long fissure. This historical context underscores the potential impact that a similar eruption could have on the modern urban environment. It highlights the necessity for an effective volcanic hazard monitoring and mitigation strategy, which is managed by the Saudi Geological Survey's National Program for Earthquakes and Volcanoes. To enhance monitoring capabilities and mitigate volcanic risks, seismic and specific volcanic monitoring stations are being integrated into the geohazard monitoring network of the Saudi Geological Survey.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Forecasting the evolution of the 2021 Tajogaite eruption, La Palma, with TROPOMI/PlumeTraj-derived SO2 emission rates

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As global populations grow, the exposure of communities and infrastructure to volcanic hazards increases every year. Once a volcanic eruption begins it becomes critical for risk managers to understand the likely evolution and duration of the activity to assess its impact on populations and infrastructure. Here, we report an exponential decay in satellite-derived SO_2 emission rates during the 2021 eruption of Tajogaite, La Palma, Canary Islands, and show that this pattern allows a reliable and consistent forecast of the evolution of the SO_2 emissions after the first third of the total eruption duration. The eruption ended when fluxes dropped to less than 6% of their fitted maximum value, providing a useful benchmark to compare with other eruptions. Using a 1-D numerical magma ascent model we suggest that the exponentially decreasing SO_2 emission trend was primarily produced by reducing magma chamber pressure as the eruption emptied the feeding reservoir. This work highlights the key role that satellite-derived SO_2 emission data can play in forecasting the evolution of volcanic eruptions and how the use of magma ascent models can inform the driving mechanisms controlling the evolution of the eruption.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Quantifying Hydrothermal Contributions to Volcanic Deformation: The 2021 Unrest of Askja Volcano

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Understanding the mechanisms driving volcanic deformation remains crucial for eruption forecasting. This study investigates the complex relationship between hydrothermal processes and volcanic deformation at Askja volcano (Iceland), where distinct phases of acceleration and deceleration with substantial cumulative surface uplift exceeding 80 cm have been recorded since August 2021. Specifically, we examine how mechanically coupled magmatic and hydrothermal systems contribute to the observed deformation phases at Askja by implementing a thermo-mechanical numerical model using COMSOL Multiphysics V6.2. Our numerical models compare a purely elastic approach with a visco-elastic model consisting of a viscoelastic crust containing a magmatic reservoir modeled as a porous medium and a shallow hydrothermal system. Magma intrusion is simulated through a time-varying mass flux at the base of the reservoir. The model incorporates temperature-dependent rheological properties, with distinct relaxation times and shear moduli assigned to the crustal, magmatic, and hydrothermal domains. Our results reveal that accounting for both viscoelastic behavior and hydrothermal processes reduces the estimated magma intrusion rates needed to explain the observed surface displacement patterns compared to our purely elastic approach. These findings demonstrate the critical role of hydrothermal processes in modulating surface expressions of volcanic unrest, providing a framework for more accurate interpretations of geodetic observations at volcanoes worldwide.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Laboratory evidence for subsurface steam transport driving thermal anomalies at active volcanoes

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Understanding gas transport from depth to the surface is crucial to interpret signals at volcanoes, and allows eruption forecasting. A potential signal is the low-temperature geothermal anomaly, which may appear before an eruption (Girona *et al*., 2021; https://doi.org/10.1038/s41561-021-00705-4). However, the interactions between steam flow, H_2O condensation, and heat transfer in active magmatic-hydrothermal systems are poorly understood, and many questions remain open. For example, could subsurface condensation of magmatic and/or hydrothermal steam drive satellite-detected thermal anomalies at the surface of volcano-hydrothermal systems? How do porous media properties and flow conditions contribute to the heat propagation towards the Earth's surface? To address these questions, a novel experimental setup was designed to inject hot steam at constant flow rate into the bottom of a sand column. We monitored temperature variations at the top of the column using a thermal infrared camera (satellite analogue) and also along its vertical profile using thermocouples. We characterized the influence of the inflow rate, inflow temperature, sand initial volumetric water content, and column height (proxy for condensation depth). Our results reveal that the injected steam exchanges heat with the porous material, condensing, and releasing latent heat, which migrates to the column surface via advection and conduction, yielding a thermal anomaly. In addition, we analysed the results with a Finite Element Method-based numerical model coupling Darcy's Law and energy conservations using COMSOL Multiphysics. Our model is able to reproduce the vertical temperature distribution along the column and the detection time of the surface thermal anomalies under most laboratory conditions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Monitoring microdeformations at Mount Etna: modelling, insights and interpretations of shallow magma convection and replenishment dynamics

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Monitoring of volcanic inflation and deflation cycles at Mount Etna has shown characteristic changes in tilt in the order of 1 to 10 microradiants, that can be attributed to magma movements in the shallow plumbing system. This has been further supported numerically, as simulations of convective magma dynamics display oscillatory behavior in overpressures and subsequent ground deformation with periods ranging from 150 to 300 seconds (Ultra-Long Period), alongside tilt variations on the order of milliradiants. This research focuses on one-way coupled, time-dependent models of magma and rock interactions during multicomponent magma convection and mixing using the multiphysics finite element software GALES (Garg et al., 2021). These simulations explore different chamber-dyke systems, capturing the complexity of magma transport and mixing mechanisms within Mount Etna's subsurface; providing new insights into the interplay between magma storage regions throughout the volcanic system. Our model embeds a computational domain encompassing an area of 100 x 100 km with a depth of 50 km. Topographic features and heterogeneities in the rock properties derived from seismic tomography data are also accounted for. The signal recorded by real multiparametric monitoring stations on the surface are used for comparison with computed signals at corresponding locations. Synthetic space-time ground deformations are analysed against recorded tilt measurements obtained during the IMPROVE multiparametric experiment in July 2023. These findings have the potential to improve the interpretation of observed replenishment dynamics and the interactions between various storage regions within volcanic systems, shedding light on their individual contributions to observed surface deformation.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Dyke-induced seismicity: depth-dependent acoustic emissions and strain in rock deformation experiments

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Understanding dyke intrusions and related seismicity is a key tool in forecasting volcanic eruptions. Modified triaxial experiments were conducted on brittle volcanic rocks using heated and pressurized plexiglass as an analog for rhyolitic magma. Experiments simulated depths of 1, 2 and 3 km respectively, in each case inducing tensile failure in the host rock through conduit overpressure. Acoustic Emission (AE) monitoring captured microseismic activity (a proxy for field scale earthquake activity), while radial strain measurements linked AE observations to fracture dynamics. Preliminary results reveal complex depth-dependent mechanical and AE behaviors: All experiments showed radial dilation before failure. At 1 km, exponential AE increase precedes tensile failure, followed by an AE peak (50/10 s), a gradual pressure drop from 6 to 5 MPa and abrupt strain increase. At 2 km, minor AE activity precedes failure, followed by a peak of 78 AE/10 s, correlated with a sharp pressure drop from 9.5 to 1.5 MPa and ~2% strain increase. At 3 km, few high-energy AE events (8/10 s) accompany a 1 MPa pressure drop and no strain changes, followed by gradual pressure increase, immediately followed by a large (main) drop of 9 MPa with 180 AE/10 s and ~3% strain increase. Post-failure AE activity diminished significantly at greater depths. Our experiments show that greater conduit overpressures are required to induce tensile failure at depth, and how crustal depth influence seismic activity related to dyke initiation and propagation, providing useful insights to understand precursor activity in active volcanoes.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Long-term volcano-tectonic unrest on the Reykjanes peninsula: Europe's unique natural laboratory for studying the depth-dependent interaction of magmatic and tectonic processes

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Volcano-tectonics delves into the intricate interplay between volcanic and tectonic activity. The detailed mechanisms governing how magmatic intrusions form, migrate, and interact with the crust remain largely enigmatic. The Reykjanes Peninsula in southwest Iceland is a natural laboratory for studying volcano-tectonic phenomena. This region, sculpted by oblique rifting, active volcanism and geothermal processes, lies along the divergent tectonic boundary of the North American and Eurasian plates. Since 2020, after almost 800 years of volcanic quiescence, new magmatic intrusions have spurred a major international collaboration supported by the Hazard Assessment and Risk Team (HART) project. Between 2021 and 2023, four intrusions and three volcanic eruptions occurred at Fagradalsfjall, followed by nine volcano-tectonic events at the Sundhnúksgígar crater row within the Svartsengi volcanic system from 2023 to 2024. These events provided an unprecedented opportunity to observe volcano-tectonic processes in real time. Using state-of-the-art tools and methods, including fiber optic cables, seismic networks, repeated gravity surveys, satellite and drone radar imaging, hyperspectral cameras, machine learning, and modeling techniques; we've captured the region's volcano-tectonic activity in unprecedented detail. Our findings illuminate critical processes, including the connectivity between magma reservoirs and the feeding system at the brittle-ductile transition zone at around 6 km depth, transtensional fault reactivation amplified at topographic highs, continuous sinkhole formation, and the re-filling of an active shallow magma domain. This suggests that the Reykjanes Peninsula is Europe's leading hub for volcano-tectonic research. We show examples of how this unique lab advances our understanding of processes and their complex interactions.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Harnessing Public-Private Partnerships – A Pragmatic Approach Towards Volcano Monitoring in Canada

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Volcano monitoring is a critical aspect of risk reduction and disaster management in regions with active or potentially hazardous volcanoes. While British Columbia (BC) and Yukon host numerous potentially active volcanoes, with at least 54 Holocene eruptions, there has not been an eruption in Canada in living memory. Recent studies estimate the annual probability of an eruption to be at least 1 in 200 and five BC volcanoes are classified as being “high” to “very high” threats. However, due to their typically remote locations and relatively infrequent activity, Canada has prioritized disaster preparedness for other natural hazards, leaving volcanic risks largely unaddressed until very recently. As the existing regional seismic network (Canadian National Seismograph Network) is not optimized for volcano seismology, a Synthetic Aperture Radar Interferometry volcano monitoring system is currently under development by Natural Resources Canada. There is nevertheless a clear need to establish continuous ground-based monitoring in advance of any future eruption. This study explores the development of a public-private partnership (PPP) to initiate and sustain a ground-based volcano and landslide monitoring network on Q̓welq̓welústen / Mount Meager (in SW BC). Drawing from successful PPP models in other sectors, we present a framework for and discuss the challenges of collaboration between private enterprises, academia, government agencies, Indigenous and non-Indigenous communities, and nonprofit organizations. By leveraging new low-cost technologies, shared resources and diverse funding mechanisms, PPPs can offer a pragmatic approach to the development of volcano monitoring networks.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

FEVER: Forecasting Eruptions at Volcanoes after Extended Repose

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Volcanic unrest is often described as complex and highly variable, especially after a volcano has remained several centuries in repose. The description may be convenient for managing expectations about the ability to forecast eruptions, but risks promoting a mind-set that volcanic systems are too complicated to follow a shared set of pre-eruptive trends. It is also popular to apply statistical methods on a case-by-case basis to identify combinations of behaviour that may signal an eruption. The results are empirical and cannot be transferred from one volcano to another. Project FEVER takes the opposite view; that patterns of unrest can be interpreted in terms of deterministic processes and transferable between volcanoes. At volcanoes restless after extended repose, for example, magma must break open a pathway through the crust before it erupts. The fundamental mechanics of crustal rupture occurs under restricted ranges of physical conditions and these, in turn, promote repeatable and quantifiable patterns of deformation and fracture. Our philosophy is supported by new laboratory and theoretical studies of rock failure in extension. They reveal that accelerating rates of seismicity observed before eruption are consistent with progressive strain softening in crust being stretched above a zone of increasing pressure (*e.g.*, of magma or high-temperature fluids). The rate of softening can be quantified to constrain forecasts of rupture. It has thus the potential to enhance operational procedures – and we will test its performance through integrating our objective, physics-based criteria into current forecasting procedures that rely on probabilistic analysis.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Short-term eruption forecasting in the next decade: A new era of high-resolution thermal infrared data

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Globally, most active volcanoes present subtle temperature changes prior to increased activity and eruption onset. Our recent work shows this is accurate 80% of the time, with some exceeding 95%. Over time many of these volcanoes also produce passive, gas-rich plumes that can evolve into more ash-rich emissions during eruptive phases. However, the ability to detect these changes is hindered by the lack of ground-based thermal infrared (TIR) instruments and the limitations of prior orbital TIR sensors. These data must have sufficiently high temporal and spatial resolution to establish each volcano's baseline and capture precursory eruption trends that deviate from that baseline. The next era of TIR data will see both portable and inexpensive ground-based systems coupled with new orbital missions that have vastly improved spatial, spectral, and temporal resolutions. Retrieval of a 1-2 degree temperature change over 60 meters each day will become a reality. One of these, the new Surface Biology and Geology (SBG) TIR mission, is now in development with the potential to greatly expand quantitative orbital volcanology. NASA is planning a suite of standard data products for SBG including Volcanic Activity (VA) for > 900 targets. The VA will contain model-based retrievals of SO_2 and ground temperature with an overall indicator of each pixel's activity state. Here we present initial results from a new ground-based TIR camera system designed to provide VA algorithm calibration and establish the volcanic activity state. These results are compared to past satellite thermal trends and projected forward to future SBG-based forecasting.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Dike intrusion simulation in 3D stress field using discrete element method

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Recent sensitive monitoring enables us to detect the small precursors of subsurface magma migration like volcanic earthquakes and crustal deformation, and to issue the warning on the forthcoming volcanic eruption. In this study, we develop a numerical simulation of dike migration using the discrete element method. Volcanic crust is modeled by 30,000,000 discrete elements of 10 meters radius, for 10km x 10km x 10km area. After the gravity packing, we assign magmatic area with initial excess pressure, and formulate magma migration 3D stress field. Numerical simulation results suggest that the threshold to decide eruption / failed eruption is the excess pressure, about 10 times of lithostatic pressure. In this model, a volcanic earthquake is modeled by the breakage of connection between elements. The stress concentration and opening are remarkable in the boundary area between the magma and the surrounding crust, indicating that earthquakes are occurring in this vicinity. The stress drop is related to the predominant frequency of the earthquake with small and high frequencies. It is noted that at the beginning of the dike penetration, low frequencies tend to predominate at depth, but high frequencies tend to predominate as they ascend. In the case of the failed eruption due to insufficient initial excess pressure, it has been confirmed that an earthquake with a predominant low frequency will continue to occur by repeating stress concentration and descent at almost the same point in the depths.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Are there thermal precursors to eruptions detectable by satellite? Evaluating 22 years of global medium resolution satellite thermal observations at 195 erupting subaerial volcanoes

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Temperature changes at volcanoes can reveal trends that could anticipate eruptions. Using nighttime Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) observations with medium spatial resolution (90 m/pixel), we manually collect thermal measurements for 195 subaerial volcanoes with 810 eruptions from 2000-2022 to evaluate thermal precursors. This is a larger sample of volcanoes than possible with ground-based thermal sensors (55 volcanoes) or detected by lower spatial resolution satellite imagery. Roughly 22% of the eruptions have sufficient cloud-free observations to construct statistically significant time series. On average, each volcano has 3 thermal features, so there are 532 individual time series. We use our Deviation From Thermal Time Series Baseline (DTTSB) program to identify temperatures that deviate from previous values and compare them to eruption times from the Global Volcanism Program to find precursors. There are 99 instances (19%) of increase in temperature before eruption, 27 instances (5%) of decrease in temperature, 58 instances (11%) of increase then decrease trends, and 348 instances (65%) where there is sufficient data, but no precursor to eruption. Thermal precursors start between one week and five years before an eruption; however, most precursors last less than a year. We find that all kinds of thermal precursors are present in all volcanic and eruptive characteristics. We also find that the size and duration of the precursor do not indicate size of the subsequent eruption. Finally, we show several examples where more temporally dense cloud-free satellite observations at spatial resolution of 90 m/pixel or better are needed.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Optimising volcano monitoring network: ensuring reliability and redundancy on data transmission Marapi case

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Volcano monitoring relies on a multifaceted approach, with seismic and deformation networks playing critical roles in detecting early signs of volcanic unrest. Seismic monitoring captures ground vibrations, and deformation networks track surface changes, both could be linked to volcanic activity. Together, they provide essential data for understanding volcanic systems and forecasting eruptions. Complementing these efforts, data transmission networks ensure real-time transmission of critical information, enabling effective early warning and disaster preparedness. However, continuous real-time monitoring is challenging due to environmental conditions and the risk of instrumental loss due to volcanic activity. Using Marapi volcano, Sumatra, as example, this study explores optimizing data transmission by analyzing reliability and redundancy. Results show that removing stations near observatory reduces reliability and redundancy scores, while removing distant stations obscured by terrain improves these metrics. Placing new stations near observatory and at higher elevations enhances performance. The findings emphasize that station positioning relative to observatory improves transmission reliability and redundancy, ensuring effective real-time monitoring. Stations behind the volcano degrade performance, making their removal beneficial without significantly affecting the network's functionality. This work is limited to data transmission and does not address the stations' ability to detect volcanic unrest, such as deformation and seismic activity. To integrate data and physical modeling to better understand volcanic systems, reliable data transmission is essential, as it ensures timely availability of critical information for analysis. Future research will focus on optimizing seismic and deformation monitoring networks, ultimately integrating all three into a cohesive framework to enhance volcano monitoring and preparedness.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Data assimilation in volcanic deformation

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Data assimilation combines numerical modelling and observational data and is now being applied across various fields in Earth sciences. Here, we propose new data assimilation methods for volcanic eruptions. We developed an elastic deformation model based on the finite element method and carried out identical twin experiments. Data assimilation experiments were performed by applying the Kalman filter and the adjoint method. The surface displacements from the true model were perturbed with independent Gaussian random noise to represent the actual observation data estimated by time-series Interferometric Synthetic Aperture Radar (InSAR) analysis. By assimilating the ground deformation data, the state of the magma chamber was estimated. In the Kalman filter experiment, a magma chamber initially placed at a location different from the true location was sequentially adjusted by data assimilation. The results show that the magma chamber depth analysis converged to the true state by assimilating data for eight steps (equivalent to two months) likely because the depth direction has a significant impact on ground deformation observation. In the adjoint method, the surface stress field of the magma chamber is estimated by minimizing the difference between the observed and model-predicted surface displacements. Here, the goal is to accurately determine the surface stress field of the magma chamber, assuming its location and size are known. The results showed convergence after approximately 50 iterations, successfully reproducing the target stress field.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Examination of the causes of geomagnetic changes observed during periods of volcanic unrest based on numerical modeling

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Geomagnetic observations around the active craters of volcanoes provide information on the thermal conditions underground, which is extremely useful for understanding volcanic activity. This aims to measure changes in the magnetization structure inside the volcanic edifice caused by heat supply from the deep as geomagnetic changes. However, when continuous observations are performed, there are cases where the geomagnetic changes remain unchanged even though other mechanical observations indicate increased activity or are observed at a different time from the increased activity. For example, at Kusatsu-Shirane Volcano, ground deformation suggesting the inflation of the underground was continuously monitored in association with increased seismic activity from March 2014. Still, geomagnetic changes were only observed for a short period in May 2014. In this study, we numerically examined this difference in the timing of activity from the perspective of changes in the magnetization structure around the assumed source of ground deformation. As a result, it was found that in volcanoes composed of weakly magnetized andesitic rocks such as Kusatsu-Shirane Volcano, even if thermal demagnetization occurs, no changes can be observed depending on the depth at which it occurs, and that the speed of change differs depending on whether demagnetization is caused by thermal conduction of the rocks or advective heat transfer due to high-temperature fluids.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Eruption probabilities from seismic data assimilation: Insights from the 2023 paroxysms of Shishaldin Volcano

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Connecting geophysical observables to subsurface processes is crucial for interpreting volcanic unrest and forecasting eruptions. Tremor, a persistent ground vibration often recorded at active volcanoes, is a key pre-eruptive indicator. Variations in tremor, such as changes in dominant frequency, overtones, or seismic amplitude, are sometimes observed before eruptions. However, similar changes can also occur during quiescence or declining activity, raising questions about how tremor reflects the physical and geometrical conditions of shallow volcanic conduits and whether it can reliably indicate pressure changes and eruption probabilities. To address this, we introduce a novel data assimilation framework that integrates seismic data, a physics-based tremor model, an inversion method using Reversible Jump Markov Chain Monte Carlo (RJ-MCMC) to constrain model parameters, and a genetic algorithm for real-time optimization of eruption probabilities. Our model, extending from Girona et al. (2019), posits that tremor arises from gas entering shallow magma systems, accumulating temporarily in the conduit, and ultimately escaping via permeable flow. We tested this framework on the 13 paroxysms of Shishaldin Volcano, Alaska, between July and November 2023, all preceded by tremor variations. Our results suggest these events were driven by a combination of magma ascent, increased gas flux (consistent with satellite observations), and partial conduit sealing, all leading to pressure rises of several MPa and increased eruption probabilities within hours. This approach demonstrates the potential for near-real-time, physics-based eruption forecasting using tremor data. Girona, T., Caudron, C., & Huber, C. (2019), https://doi.org/10.1029/2019JB017482.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Characterizing pre- and syn-eruptive processes at Great Sitkin Volcano, Alaska, by integrating seismic data assimilation and satellite-based thermal anomalies

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A deeper understanding of the state of unrest at active volcanoes can be achieved by combining robust physical models with multidisciplinary observations. For instance, the leaky gas pocket model (Girona et al., 2019) connects seismic long-period (LP) and tremor waveforms to key physical parameters that influence volcanic unrest, while subtle thermal anomalies may provide insights into the transport of fluids in the shallow subsurface (Girona et al., 2021). Here, we integrate the leaky gas pocket model into a data assimilation framework to investigate the LP activity associated with the ongoing dome-building eruption of Great Sitkin Volcano, Alaska, which began in 2021. Specifically, using a Bayesian Markov Chain Monte Carlo approach, we provide initial parameter estimates, while a genetic algorithm–based data assimilation method tracks parameter evolution over time. Preliminary results indicate a shallow conduit permeability of around 10^{-7} m^2 prior to the explosive May 25, 2021, eruption, decreasing to 10^{-12}-10^{-7} m^2 during the initial effusive eruption in July 2021. We are also analyzing the spatiotemporal distribution of subtle thermal anomalies using Moderate Resolution Imaging Spectroradiometer (MODIS) data to gain a more detailed understanding of very shallow subsurface conditions. By integrating subtle thermal anomalies into our seismic data assimilation framework, we aim to better identify the conditions leading to dome-building eruptions, elucidate the parameters governing explosive-to-effusive transitions, and refine our understanding of the pre- and syn-eruptive processes at Great Sitkin Volcano.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Investigation of thermo-hydrodynamic processes preceding the different eruption styles observed in a laboratory geyser

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Diverse eruption styles observed at geysers may be related to the plumbing geometry and thermo-hydrodynamic conditions. We expect insights into the eruptive cycle variability of volcanoes through understanding the physical controls of geyser eruptions. This study conducted a laboratory experiment simulating geyser eruptions with a simple setup comprising a vertical pipe and a flask. As reported in the previous studies, we had two eruption styles: major eruption, characterized by vigorous spouting and large discharged mass, and minor eruption with calm effusion and small discharged mass. Although the size of an eruption controlled the time to the next eruption, the size of the next eruption was not necessarily predictable. We explored the branching point of the major and minor eruptions. Both eruptions appeared to occur irregularly, but major eruptions were often followed by small eruptions. We observed and compared multiparametric time evolutions, including pressure, temperature, bubble generation in the flask, and bubble ascent in the pipe. We found that the bubble increase rate in the flask a few seconds before a major eruption was higher than that of a minor eruption by analyzing the video data. There were no apparent differences in most of the quiescence time (approximately 100–1200 seconds, depending on preceding eruptions) to that point. It is inferred that the thermodynamic condition and progressive process of the decompression boiling in the flask just before the eruption are the critical factors controlling the eruption styles. We need further investigation to clarify how this branching point is formed.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Using Cross-Entropy as a Volcanic Precursor: the case study of the 2021 Tajogaite Eruption (La Palma, Spain)

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This study investigates the application of seismic cross-entropy as a possible geophysical precursor of volcanic activity in the Canary Islands, with a special focus on the 2021 Tajogaite eruption (La Palma, Spain). Using data from the Red Sísmica Canaria, which comprised seven seismic stations operational during the eruption period, we calculated temporal variation in seismic entropy for each station and seismic cross-entropy for all possible station pairs. The results show a significant and widespread decline in cross-entropy in the hours preceding the eruption. Additionally, we performed a spatiotemporal analysis using two-dimensional Gaussian interpolation. This allowed us to create cross-entropy maps, revealing that the minimum cross-entropy values were concentrated precisely in the area where the eruption occurred. These results suggest that cross-entropy can be a valuable indicator for the early detection of volcanic eruptions, providing an additional tool for volcanic monitoring and risk mitigation. This tool has computation times low enough to be implemented in real-time. We maintain that this study highlights the importance of cross-entropy in seismo-volcanic monitoring and its potential application in other volcanic contexts.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Do shape and size of erupted tephra reflect their porosity? An investigation of representative tephra from explosive eruptions at Mt Etna (Italy)

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Volcanic eruption forecasting is vital for ~1.1 billion people living near volcanoes worldwide, and remains incredibly challenging. It is crucial to develop new approaches for enhancing monitoring and forecasting of volcanic eruptions and applying promptly risk mitigation strategies. The size and porosity of erupted tephra are important parameters that can be variably used to determine the level of pre-eruptive gas storage and pressurization of magma, eruption style and intensity, and volcanic particle dispersion. To date, a potential correlation between the size of tephra with irregular shapes and porosity resulting from vesiculation in pre- and post-fragmentation stages of the erupted magma remains obscure. Here we present new data highlighting the possible correlation between tephra shape and size and porosity based on an interlaboratory analysis of a set of representative samples from Mt Etna (Italy) derived from fall-out deposits of the 122 B.C. Plinian eruption, 1669 initial strombolian phase, and paroxysms events of 2001 cycle, 2002-2003 phase, February 2021, February 2022, August 2023, and July 2024. We investigated lapilli size tephra ranging 2 and 30 mm using a dynamic image analysis on a CAMSIZER, a particle size and shape analyser. The porosity of selected samples is currently explored using a gas pycnometer. Tephra size and shape analysis shows monodisperse and polydisperse distributions that are currently being interpreted. We aim to demonstrate how dynamic image analysis via CAMSIZER may offer a prompt assessment of sample porosity resulting into a near-real-time monitoring of gas accumulation in magma during eruptions at Mt Etna.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Probabilistic Failure Forecast Method (FFM) of geochemical observables to forecast the time of geological events in volcanic systems

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Voight (1988, 1989), Voight and Cornelius (1991) and Cornelius and Voight (1995) proposed their material Failure Forecast Method (FFM), starting from the study of the Mt. St. Helens eruption. Since then, most of the FFM implementations have been applied to geophysical observables such as deformation and seismicity. The energy released by the diffuse volcanic degassing process is considerable, and it cannot be neglected in the energy balance of a volcanic systems. Since gas emission rates and/or chemical variations may be influenced by several factors associated with brittle fracture associated to volcanic unrest or eruptions, the rapid increase in these geochemical observations, prior to geological events in volcanic systems, can be considered as a geochemical precursor. After selecting an appropriate time window in the geochemical time series, we can apply the Failure Forecast Method (FFM) to forecast the time of a significant geological event like a volcanic unrest or eruption. In this work, we propose the application of the FFM in a probabilistic fashion (PFFM) by using the bootstrap method. For each geochemical parameter we obtained a probability distribution of the intercept time. Specifically, we use the 5th and 95th percentiles to define the 90% confidence range. Since most of the obtained probability distribution are highly multimodal, and with numerous outliers, we considered using the median instead of the maximum likelihood of the mean value to estimate the most reasonable forecast date. (B. Voight, Nature, 1998; B. Voight, Science, 1999; R. Cornelius and B. Voight, JVGR, 1995)

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

FEM model of surface deformation pattern applied to the Campi Flegrei caldera

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Campi Flegrei is the largest active urbanized caldera in Europe. Since 2005, it has shown slow but progressive ground inflation and, in recent years, an increase in seismic activity. Deformation is characterized by transient reversals in rate, leading to episodes of monotonic uplift lasting from several weeks to a few years. Additionally, some aseismic transients have been detected using high-sensitivity strainmeters and long-baseline tiltmeters, with amplitudes typically below the noise level and durations shorter than the sampling frequency of most geodetic techniques. A shallow hydrothermal origin for the ongoing deformation may explain non-eruptive cycles of subsidence and uplift, driven by the balance between magmatic input and fluid discharge at the surface. However, separating signals from magmatic and hydrothermal sources is challenging due to the presence of both types of reservoirs. A detailed study of ground deformation using a finite element model is essential to understand the kinematics of both the aquifer and the plumbing system at different depths. In this study, we used COMSOL Multiphysics to examine how deep pressure and temperature changes influence surface deformation in the Campi Flegrei caldera. The Tough software, simulating multi-phase fluid and heat flows, was used to model the sources which, within the COMSOL model, has shown a good match with observed surface deformation data from GPS/GNSS and strainmeter time series, confirming the model's accuracy. Combining data and models makes it more feasible to forecast volcanic system parameters on relevant timescales. Data used contains valuable information for scientific community, following EPOS policies.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Training deep learning networks with models integrating complex rheologies in the magmatic system: An advance to forecast time series models of volcanic deformation

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Over the past three decades, InSAR has revolutionized volcano monitoring, offering unmatched insights into global volcanic behaviors. Interferograms reveal the large variations in magmatic reservoir geometries, while time series data illuminate magma dynamics and complex subsurface processes occurring at depth. Despite these advances, the diversity of volcanic behaviors poses challenges for forecasting modeling. Recent machine learning and deep learning techniques have shown promise in identifying and localizing volcanic deformation in interferograms and have been useful to create alerts of volcano activity based on temporal or spatial changes observed in InSAR time series. However, these methods have not yet been applied to forecast the temporal evolution of surface deformation in volcanoes. This study addresses this gap by integrating global observations of volcanic deformation with numerical simulations to train deep learning networks capable of forecasting volcanic uplift episodes. Using a decade of Sentinel-1 observations, the study identifies global patterns in the temporal evolution of volcanic uplift. Building on recent research highlighting the mechanical complexity of magmatic systems, it incorporates advanced physical models that simulate realistic deformation scenarios. These models account for viscoelastic and poroelastic processes to reflect the influence of high-temperature rock and fluid behaviors on volcanic deformation. By combining InSAR data, dynamic modeling, and deep learning, the study develops a robust framework for forecasting volcanic deformation. This approach not only advances our understanding of volcanic systems but also enhances global volcanic hazard forecasting. Bridging monitoring and alert systems, it offers a transformative tool to improve safety and preparedness for communities worldwide.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

A trans-dimensional inversion algorithm to model deformation sources with unconstrained shape in finite element domains

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Geodetic measurements provide insights on deep processes occurring in active volcanic areas. Inverse modeling is employed to interpret these signals and estimate the parameters that describe magma chambers or dike intrusions. Despite the robustness of the available techniques, realistic source representations are still challenging. Analytical models offer rapid solutions that are useful for facing urgent requests during unrest but assume an isotropic elastic crust and define a-priori simple source geometries. Numerical models implementing finite element methods (FEMs) account for the topographic load and crust heterogeneity effects but require longer computational time. In this study, we present a new, efficient, FEM-based modeling approach for full data-driven source shape definition. We approximate a source of potentially any shape aggregating cubic elements of a FE-mesh loaded with a stress tensor. The deformation field is obtained by the linear combination of each unit contribution, scaled with factors depending on the source geometry. With this strategy, we avoid re-meshing, reproducing the deformation patterns of pressurized cavities in a fixed and continuum domain. A library of pre-computed surface displacement, related to each unit in a user-defined volume, is managed by an original trans-dimensional inversion algorithm. This code shapes the source that best fits the observations, aggregating these units and combining their responses. We employ two competing sets of 3D Voronoi cells to sample the model domain, defining which unit belongs to the source and the inactive crust. This software uses parallel computing for optimal performance and is designed to be adaptable to any volcano.

Theme: 2. Pre and syn-eruptive monitoring

Session 2.4: Towards Enhanced Forecasting of Volcanic Systems: Monitoring and Beyond

Allocated presentation: Poster

Volcanic unrest detection using trans-dimensional McMC: application to dike intrusion events at Mount Etna

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Volcanic monitoring is conducted at observatories worldwide through the analysis of continuously updating time-series from the geophysical monitoring network. The detection of upcoming unrests, typically characterized by anomalous signals from geodetic and seismic stations, is crucial for the early warning management. However, due to the presence of noise of different nature, difficult to suppress in near real time, the time gap between the beginning of the anomaly and the issuance of the unrest warning is challenging to be minimized. Several approaches spanning from traditional statistics to machine learning have been tested in the literature, given the need for ever more accuracy. We test the performances of trans-dimensional Markov-chain Monte Carlo methods to detect sudden changes in multivariate time series. The case study of Mount Etna dike intrusion event of the 24th December 2018 is used to simulate the near real time data arrival. The main advantage of this method is the full data-driven change point selection, thanks to the changing dimensionality of the problem. We are able to avoid false alarms thanks to the joint inversion of multiple GNSS stations and other geophysical signals. Multiple independent chains in a computationally efficient framework, reveals peaks of sampled models frequency at the location of the target events in both synthetic and real datasets. We compare the timing of our warning outputs to those obtained with classical methods. We prove that the proposed approach constitutes a highly sophisticated and efficient tool for monitoring activity support.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

Graph Neural Network based elastic deformation emulators for magmatic reservoirs of complex geometries

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Measurements of volcano deformation are increasingly routine, but constraining complex magma reservoir geometries via inversions of surface deformation measurements remains challenging. This is partly due to deformation modeling being limited to one of two approaches: computationally efficient semi-analytical elastic solutions for simple magma reservoir geometries (point sources, spheroids, and cracks) and computationally expensive numerical solutions for complex 3D geometries. Here, we introduce a pair of Graph Neural Network (GNN) based elasto-static emulators capable of making fast and reasonably accurate predictions (error upper bound: 15%) of surface deformation associated with 3D reservoir geometries: a spheroid emulator and a general shape emulator, the latter parameterized with spherical harmonics. The emulators are trained on, and benchmarked against, boundary element (BEM) simulations, providing up to three orders of magnitude speed up compared to BEM methods. Once trained, the emulators can generalize to new reservoir geometries statistically similar to those in the training data set, thus avoiding the need for re-training, a common limitation for existing neural network emulators. We demonstrate the utility of the emulators via Bayesian Markov Chain Monte Carlo inversions of synthetic surface deformation data, showcasing scenarios in which the emulators can, and can not, resolve complex magma reservoir geometries from surface deformation. Our work demonstrates that GNN based emulators have the potential to significantly reduce the computational cost of inverse analyses related to volcano deformation, thereby bringing new insights into the complex geometries of magmatic systems.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

A ConvLSTM based deep neural network for volcanic clouds monitoring from space

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Active volcanoes present significant hazards at various geographic scales. Volcanic clouds produced during explosive eruptions affect human health, climate, and aviation safety. Therefore, accurately capturing the temporal evolution of volcanic clouds is critical for understanding their dynamics and improving predictive capabilities. Given the highly dynamic nature of explosive eruptions, volcanic clouds can form, expand, and disperse rapidly. Therefore, high-temporal-resolution geostationary satellite data, such as that from MSG-SEVIRI (Meteosat Second Generation - Spinning Enhanced Visible and InfraRed Imager), is indispensable for near-real-time monitoring of these events. By capturing the swift changes in cloud formation and dispersion, we can identify patterns in the cloud's evolution and composition. Here, we propose a novel approach using a convolutional long short-term memory (ConvLSTM) model, a type of recurrent neural network (RNN), to track the spread of volcanic clouds using satellite data. A dataset of Ash RGB images, captured every 5–15 minutes from native SEVIRI data, was compiled from volcanic eruptions at Mt. Etna (Italy). We show that ConvLSTM models are able to solve complex spatiotemporal problems, effectively segmenting volcanic clouds and tracking their dispersion. This model provides timely and reliable information that supports aviation safety, emergency response, and public health monitoring, thereby enhancing decision-making during volcanic crises.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

Impact of volcanic SO2-rich plumes on vegetation health

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While health and atmospheric effects of volcanic gases have been well studied, the direct impacts of gas laden plumes on their surrounding ecosystems are comparatively understudied. Of particular interest are the impacts of volcanic SO_2 on the health of surrounding forests. Although industrial SO_2 impacts on vegetation have been studied there is a lack of research in volcanic settings. Here, we present a novel remote sensing method to track vegetation health and recovery at multiple tropical volcanoes. We use optical vegetation indices and radar remote sensing to analyse vegetation health and recovery response post exposure to SO_2 rich volcanic plumes. Our data demonstrate a rapid decline in vegetation health (a decrease of up to 0.7 in NDVI), indicating SO_2 exposure resulting in damage to the photosynthetic processes of adjacent forests. The post-exposure recovery is rapid (recovering in as little as 5 months), particularly for that level of detected decline in vegetation health, suggesting the damage is dominated by SO_2 impacts rather than ash. These rapid recovery rates have potential to provide insight into vegetation resilience in volcanic settings. This method, while enhancing understanding of SO_2 related vegetation impacts, is also a novel tool for volcano monitoring as we can detect and map the unique response of vegetation to volcanic SO_2. We suggest that this method can aid to safely track plume trajectory and identify areas of concentrated gas exposure, thus understanding the impacts, through time, of volcanic eruptions on their surrounding ecosystems.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

A petrologist's walk through the forest of machine learning

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Machine learning (ML) is a tool that has come to the forefront of Earth science advances in recent years. ML offers new opportunities to re-evaluate current methodologies spanning geophysics, geochemical classification, thermal modelling, and thermobarometry. By improving our methodological approaches, we may uncover answers to long standing questions, for example establishing the size, vertical extent, and thermal properties of sub-volcanic magma plumbing systems. However, most volcanologists lack formal data science training, which makes the usage and development of ML models daunting. Here, we present the multi-year evolution of a ML approach to mineral thermobarometers, as an example of a successful, and continuously evolving, application of ML in volcanology. Mineral thermobarometers link the geochemical compositions of minerals to the pressure and temperature of their crystallization, allowing for a high-resolution interrogation of magma plumbing systems. Since 2020, ML approaches to mineral thermobarometry have emerged in the literature (e.g. Petrelli et al., 2020; Higgins et al., 2022). In this contribution, we present the evolution of ML clinopyroxene thermobarometers, beginning at the basics of algorithm selection and collection of the training dataset (Jorgenson et al., 2022) and ending at recent methodological advances, including feature engineering, data augmentation, bias correction, analytical error propagation, and error reduction (Ágreda-López et al., 2024). Finally, we share practical insights for volcanologists implementing ML in their research; we emphasize the need for high-quality training datasets, ensuring transparent coding practices by sharing code documentation, and making the model accessible.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

In search for ground-truth. Quantifying uncertainty in expert labelling for machine learning

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High-quality ground-truth labels are essential for training reliable and accurate deep learning models. While advances in the automatic classification of volcano-seismic signatures hold promise for global implementation in volcano observatories, training data often remain sparse and are typically labelled by a single expert, with uncertainty frequently overlooked or unquantified. This study investigates the level of agreement among experts when classifying volcano-seismic signatures, highlighting potential ambiguities in the training data that may impact model performance. The specific objectives of this study are: (1) to evaluate agreement among experts on volcano-seismic signatures, and (2) to develop an agreement-based classification method for volcanic earthquakes. The study involves designing an online questionnaire, distributed globally to volcano experts, and asking participants to classify volcano-seismic signatures into predefined categories: volcano-tectonic, long-period, hybrid, and other. Participants will provide a likelihood score on a continuous scale from -1 (certain the signal did not belong to the category) to 1 (certain the signal did belong to the category). Annotator agreement and uncertainty will be assessed using Kendall's W and Fleiss' Kappa, both robust statistical measures of inter-rater reliability. Ground-truth labels will be assigned probabilities based on the maximum likelihood derived from all discrete classes. Incorporating uncertainty into the data provides transparency in the machine learning process and may offer insights into whether the current standard classification groupings are truly adequate for precise volcano monitoring practices.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

Mitigating Atmospheric Noise in InSAR Displacement Time-series using a Convolutional Neural Network Machine Learning Model

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Atmospheric artifacts are a common cause of noise in InSAR data that can mask deformation signal related to volcanic activity. While several techniques have been developed over the past few decades to mitigate atmospheric noise, the success of these techniques is highly variable depending on the regional setting, and in some cases can even introduce more noise. We introduce a Convolutional Neural Network (CNN) trained to predict deformation from input consecutive unwrapped InSAR displacement maps. The CNN framework consists of a U-net structure that runs the input data through a series of convolution and deconvolution layers to handle the dimensionality of such a large image dataset, as well as to improve the model's generalization capacity. For model training, we simulate ground deformation from a magma storage region using a Mogi point source at depth undergoing various volume changes (linear, step-wise, sinusoidal) through time. The resulting input data consists of 5000 unique time series of 20 unwrapped deformation maps each that are read into the CNN; we also test whether adding simulated atmospheric noise or downloaded atmospheric phase maps from GACOS to these deformation time series trains the CNN to produce better deformation predictions from CosmoSkyMed unwrapped interferograms over Masaya volcano in Nicaragua.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

VolcanoInSight: A webcam system for monitoring volcanic activity in Iceland

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We present VolcanoInSight, a webcam based system developed by the Icelandic Meteorological Office to monitor active volcanoes. A network of webcams is maintained around the country to measure the heights of ash clouds, gas plumes and fire fountains, as well as locate new vent openings and digitize lava flow fronts. For this purpose the cameras need to be calibrated, either in the laboratory using calibration targets or vicariously using stars and features in the landscape. The orientation of each camera is then found by matching the stars or the horizon in the image with those from astronomical almanacs or digital elevation models, respectively. This matching is performed either manually or automatically using a horizon scanning algorithm, which also retrieves the focal length in the case of Pan Tilt Zoom cameras. If the location of the camera is not accurately known it is refined using a Bayesian Optimisation process. Once calibrated and oriented, measurements are made by either triangulation, DEM intersection, or by placing geometric constraints using known vent locations and wind directions. Measurements are made using a website that saves results to a centrally accessible web mapping server so observations from a team can be synthesised by a single user in a GIS for e.g. real time lava flow monitoring during a crisis. VolcanoInsSight works with stills, and a video enabled version is under development for calculation of rate-based quantities (e.g. plume rise speeds, fluxes) and useful visualisations. Examples will be presented from recent activity on Reykjanes.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

Colonization of basaltic lava by lichens at Fagradalsfjall volcano (Iceland) imaged using drone-based hyperspectral remote sensing

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Lichens are among the first organisms to colonize cooled lava flows, offering insights into volcanic landscapes, including, e.g., relative age and weathering intensity. Substrate properties such as porosity, permeability, texture, and mineral composition play an essential role in lichen community establishment. While lichens primarily obtain nutrients and minerals from the air, they are also considered to engage in a complex chemical exchange with the underlying rock surface. However, the relationship between lichen occurrence and the geochemical composition of lava remains underexplored. Investigating these rock-lichen interactions could provide valuable insights into the geochemical characteristics of volcanic materials. To deepen our understanding of interactions between lichens and volcanic rock, it is crucial to study the distribution patterns of various lichen species across different volcanic substrates. We acquired drone-based hyperspectral image data, together with field spectrometer point measurements of lichens on basaltic lava at the Fagradalsfjall volcano (Iceland) in August 2023 to characterize lichens' spectral signatures and assess their detectability for remote mapping. Using an open-source, Python-based (post-)processing workflow, we demonstrate the potential and challenges of our multi-sensor approach for mapping lichens on volcanic rocks. Although the results showed that different sensor characteristics caused offsets in the spectral signatures, we successfully derived meaningful band ratios that highlighted the presence of distinct lichen groups on the basaltic rock. These findings demonstrate the potential of drone-based hyperspectral imaging for lichen detection in volcanic environments, and thus pave the way for future studies that provide deeper insights into rock-lichen interactions.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

An ICA-based detection of volcanic deformation using InSAR data in Ontake volcano, Japan

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Independent Component Analysis (ICA), a type of machine learning, is a powerful technique that can separate Interferometric Synthetic Aperture Radar (InSAR) data into surface deformation and noise-derived signals without complex assumptions. Recent studies have applied ICA to time-series InSAR data to detect volcanic deformation (e.g. Ebmeir et al., 2016, Gaddes et al., 2019). Most of these studies have used Sentinel-1 C-band data, and few studies have applied ICA to long-wavelength L-band data. L-band data are susceptible to noise from, for example, the ionosphere, so it is expected that ICA can be more useful for extracting surface deformation components from InSAR data that contain such noise. Here, we applied ICA to the ALOS-2 L-band time-series InSAR data from 2014 to 2022 for the Ontake volcano in Japan, where the 2014 phreatic eruption occurred. The results showed that the volcanic deformation component could be separated and extracted from the noise component to the same extent as in Narita et al. 2019. Based on our results, the estimated surface deformation component around the crater could be up to 20 cm smaller than that estimated by some previous studies, in which case our method is expected to provide more accurate estimates of volcanic deformation. In the future, we aim to improve the accuracy of surface deformation estimates by confirming the consistency with the ICA-derived deformation component based on modelling results using analytical and numerical methods.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

Lessons Learned from a Community-Driven Workshop to Define Best Practices for Unoccupied Aerial Systems (UAS) Use in Volcanology.

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The use of UAS (Unoccupied Aerial Systems, a.k.a 'drones', 'UAVs') in volcanology is a thriving and fast-growing field with the potential to fill crucial gaps in our ability to collect volcanological data. Challenges are associated with such a rapidly innovating and expanding field of study. For example, specific constraints are relevant to the type of data acquisition required, country of operation, safety, and environment. Many individual research groups work this out alone and develop their best practices at an individual or discipline-specific level. Successful data acquisition relies on safely planning, permitting, preparing, and deploying UAS for volcanic research, monitoring, and disaster response. Our community would benefit from a set of best-practice recommendations based on lessons learned from across the varied sub-disciplines of volcanology. To this end, we held a workshop at IAVCEI 2023 in Rotorua, New Zealand, where we discussed challenges and real-life applications with UAS users in the volcano community. Eleven people attended in person, and 12 joined virtually over a 2-day workshop. Through a mix of guest lectures, breakout sessions, and group discussions, we explored what it takes for successful UAS missions. Discussions centered around strategies for mission success, new technologies, creating a volcano UAS community, and developing best practices for UAS in volcanology. Here, we present the findings of this workshop and the common themes that emerged from the varied discussions. We hope to bring the UAS volcanology community together and collate this information to develop a community-driven set of best practices.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

Detection of seismic phases on Distributed Acoustic Sensing (DAS) using the Discrete Cosine Transform (DCT).

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Distributed Acoustic Sensing (DAS) is revolutionising seismic monitoring and volcano seismology by transforming fibre optic cables into dense arrays of virtual sensors. This technology is particularly advantageous for studying seismo-volcanic processes, enabling high-resolution detection and characterisation of seismic phases such as P- and S-waves. However, DAS generates enormous volumes of data, often reaching terabytes, necessitating the development of efficient processing techniques to extract only meaningful information. This work introduces a novel approach for detecting seismic phases in DAS datasets. We used the Discrete Cosine Transform (DCT) to detect DAS recordings as images and apply edge-enhancement methods to highlight seismic phase arrivals. Once the different phases have been characterised, we can use absolute and relative location methodologies to determine the hypocenter location, considering that, unlike traditional sensors, it is not always possible to know the exact position of each cable section. This approach improves the spatial and temporal resolution of seismic event analysis, especially on volcanic islands or underwater areas where the seismic network distribution is geographically limited. We demonstrate the effectiveness of this methodology using DAS datasets from submarine cables located near the islands of Tenerife and La Palma (Canary Islands). The dataset includes the seismic activity recorded during the 2021 Tajogaite eruption, showcasing the potential of combining DCT-based detection with earthquake location techniques for real-time volcanic monitoring. These advancements emphasise the role of innovative data processing in harnessing DAS to improve our understanding of volcanic processes and hazard mitigation.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

A Cutting-Edge AI Approach for Ground Deformation Modelling

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The dynamics of the plumbing system directly results in ground deformation in volcanic regions reflecting the complex shape of magma intrusions, the volume of magma entering or rising, and the mechanisms of emplacement. Accurate interpretation of ground deformation data, critical for monitoring a volcano, has prompted the development of several methodologies and models to understand the underlying causative sources and mechanisms. However, traditional methods for interpreting ground deformation data usually rely on simplified mathematical models and manual analyses, which can be time-consuming and less accurate due to the complex nature of volcanic processes and subjective choices of the analyst. On the other hand, more complex models such as numerical approaches (e.g. FEM) can provide more realistic solutions, but at the higher computational and temporal cost; therefore, they cannot be considered for real-time applications. Recent advances in Artificial Intelligence may prove useful by potentially offering an automatic and more accurate tool for encoding complex patterns in deformation data and leading to better predictions of volcanic activity. By taking advantage of the automation of deep learning, a novel inversion methodology has been approached with a combination of 3D deep neural networks to reconstruct the distribution of forces – the 3D source – inside the volcano that can generate the measured ground deformation. The AI model shows good ability to do instantaneous imaging of the volcanic source from station-based streamed deformation data, providing a useful tool for both monitoring and research purposes.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

Multi-vent activity and morphological changes at El Reventador volcano, Ecuador, observed through ground-based thermal and seismo-acoustic

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Changes to the summit morphology of stratovolcanoes can play a key role in controlling the dynamism of eruptions. It is unclear, however, what effect such changes may have in either the shallow plumbing system or in the generation of multi-vent activity. In April 2018, a small (>1.3x10^6 m^3) debris avalanche at El Reventador volcano produced an amphitheater oriented to the northwest of the summit. The formation of the scarp breached the summit crater and resulted in the appearance of two new vents within it. In this study, we analyze thousands of thermal images between May 2018 and February 2023 from an infrared camera located 2.8 km to the northeast (REBECA). For each REBECA image, we employ a novel processing algorithm that automatically identifies the presence and location of the columns, with some images capturing eruption columns from multiple vents simultaneously. In addition, we extract the corresponding seismo-acoustic amplitude corresponding to each thermal image in order to track the energy of the explosions at each vent over time. Together, these techniques generate a unique and high temporal resolution catalog of the explosive activity at multiple vents. We find that the rate of explosions at each vent varies significantly with time, especially as the amphitheater began to progressively fill in. Long-term multiparametric monitoring of 'laboratory volcanoes' such as El Reventador provides unique opportunities to link geophysical and visual datasets to interpretations of the underlying eruptive dynamics.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

A machine learning approach to volcanic eruption nowcasting using geostationary satellite-based thermal features

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Geostationary satellite thermal imagery has been shown to be fundamental to timely monitor volcanic eruptions. Among satellite-based monitoring signals, Volcanic Radiative Power (VRP) offers a detailed overview of the pre, syn and post volcanic behavior over time. The synergistic integration of satellite data with artificial intelligence (AI), particularly data-driven AI, has shown to solve predictive complex real-world problems positions them as an effective tool for volcano hazard monitoring. This work proposes the use of Machine Learning based on VRP-derived features to classify both the volcanic state of alert providing a probability of having an eruption and the type of volcanic activity taking place. By applying signal processing techniques on VRP records, we extracted different features, which are linked to different phases and types of volcanic activity. The learning process is driven by a vast satellite data archive acquired on Mt. Etna used as study case. This innovation proves crucial for the early identification of subtle patterns that may indicate significant changes in volcanic behavior, ultimately enhancing our ability to predict and mitigate volcanic risks. This approach offers a tool for volcanic eruption nowcasting, transferable to different volcanic systems. Importantly, VRP data used in this study are sourced from Spinning Enhanced Visible and Infrared Imager (SEVIRI) observations on the Meteosat Second Generation (MSG) satellites, providing high temporal resolution with data available every 5/15 minutes. The outcomes of this research offer promising avenues for advancing early warning systems and improving our preparedness in the face of volcanic events.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

The Virunga volcanic chain: a solution to the electricity problems of the city of Goma (North Kivu, DRC)?

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Since the volcanic eruption of 2002, most of the city of Goma has lacked electricity. The cause, the lava flows had damaged the poles of the national electricity company which carry current from Bukavu to Goma, via Rutshuru (around 200 km). The city, not having hydroelectric power stations, can thus take advantage of its biggest nightmare, the Nyiragongo volcano, and its related activities, more particularly the hydrothermal systems around the city, to produce clean electricity and be independent of neighboring regions. However, the full geothermal potential of the city is not yet known. Apart from the magma chamber of Nyiragongo reaching 1000°C and numerous thermal springs (around a hundred) with variable temperatures which can exceed 100°C on the surface around the city, Goma can also benefit from the heat produced by the magma chamber of the Nyamulagira volcano, the most active in Africa.

Keywords: Volcanic eruption of 2002, Nyiragongo, Lack of electricity, Geothermal potential, Thermal springs.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Talk

Leveraging Machine Learning for Improved Earthquake Location: A Case Study from Mayotte

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We introduce a machine learning-based method designed to refine hypocenter locations by leveraging data from dense, temporary seismic deployments alongside permanent seismic networks. The method learns to correct biases in hypocenter estimations from low-density permanent arrays using the detailed information provided by temporary stations. Under adequate assumptions, this approach enables the reanalysis of past and future seismic data, enhancing our understanding of seismic crises that occurred beyond the coverage of dense arrays. Applied to Mayotte Island following the 2018 eruption, the method combines data from ocean-bottom and land seismometers to significantly improve location accuracy, demonstrating its broad applicability in regions with sparse seismic station coverage.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Using Machine Learning to Enhance the Yellowstone Earthquake Catalog

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The University of Utah Seismograph Stations (UUSS) is responsible for earthquake monitoring in the Yellowstone volcanic region and has cataloged ~34K earthquakes with magnitudes between -1.29 and 4.83 from 2002 to 2022. While the UUSS catalog is generally complete down to M1.5, many small earthquakes and supplementary phase arrivals are not identified. Still, this information could help improve body-wave tomography models and provide insight into fault architectures, swarm evolution, dynamic triggering, and more. The nature of seismicity in Yellowstone, which is ~50% earthquake swarms, makes automatically cataloging these earthquakes challenging, however. Machine learning techniques can accurately process earthquakes and may be more reliable for periods of elevated seismicity than conventional methods. Here, we present the preliminary results for an enhanced Yellowstone earthquake catalog produced using machine learning models explicitly trained for Yellowstone. We apply a phase detection method that works well during periods of elevated seismicity to continuous Yellowstone seismic data and use an arrival time refinement method that produces Bayesian-derived uncertainties. When carefully evaluating these methods on a 10-day period containing an M_w 4.8 in Yellowstone, we identified 855 potentially new events, of which >99% were genuine, and recovered 83% of the UUSS catalog. We also use a feature-based magnitude estimation method that works well for small earthquakes and maintains consistency with the authoritative regional earthquake catalog. Ultimately, applying machine-learning methods will result in a comprehensive and detailed view of Yellowstone seismicity.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Structural parameters of the dyke swarm in the Saghro Massif (Eastern Anti-Atlas, Morocco): Insights into the understanding the depth of magma chamber source and tectonic regime during emplacement

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The Ediacaran Saghro Massif, in the eastern Anti-Atlas of Morocco, hosts extensive dyke swarms that intrude formations of the Saghro Group and the Ouarzazate Supergroup. This study investigates a dyke swarm in the central part of the massif to constrain the depth of the magma chamber source and the tectonic regime active during emplacement. A total of seventy-eight dykes were analyzed in terms of orientation, thickness, length, and geometric characteristics. The depth of the magma chamber was estimated by evaluating dyke aspect ratios and magma overpressure, incorporating parameters such as the elastic properties and density of the host rock, magma density, gravitational acceleration, and Poisson's ratio. Additionally, paleo-stress analysis was conducted to reconstruct the prevailing tectonic conditions. The findings suggest that these dykes originated from a deep-seated magma reservoir, likely near the Moho discontinuity. Paleo-stress reconstruction indicates that their emplacement occurred under a transtensive tectonic regime linked to the WACadomian orogeny. **Keywords:** Morocco, Eastern Anti-Atlas, Saghro Massif, dyke swarm, magma overpressure, magma chamber depth, transtensive regime.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Highlighting inner structures of Piton de la Fournaise by comparative analysis of unique 3D magnetic and electrical resistivity models

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Imaging inner structure of a volcanic edifice is a fundamental challenge to better understand, constrain and predict its dynamics in order to answer scientific and societal issues. Piton de la Fournaise, a highly active and well-monitored basaltic shield volcano, is an ideal site for geophysical imaging. Such approaches provide essential information to constrain the geometry and spatio-temporal evolution of its active structures at different depths. Firstly, we applied an innovative data processing approach based on a rectangular harmonic analysis to 1) compile a large magnetic dataset acquired at different spatial (ground, UAV and helicopter-borne measurements) and temporal scales (from 2014 to 2024), and 2) provide a spatially consistent dataset for 3D high resolution numerical inversion of the Terminal Cone. Secondly, we carried out a high-resolution 3D electrical resistivity tomography of the same area using an innovative approach (FullWaver method). It presents the advantage of decoupling the electrical current injection and reception systems, enabling us to cover a large area with a complex topography down to a depth of about 1 km below the summit. A detailed comparative analysis of the 3D models provides new information on the nature of the active structures and their extension within the volcanic edifice. This gives us a picture of shallow magmatic and hydrothermal systems, weakness axes and preferential path for fluid circulation at different depths. These observations constitute a new reference of structure of the volcano and will make it possible to study the spatio-temporal evolution (i.e. 4D) of Piton de la Fournaise.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Towards Automating Reliable SO_2 Camera Retrievals

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Since the development of the technique in the early 2000s, the use of UV cameras to obtain sulphur dioxide emission rates at volcanoes has become widespread. As robust, low-energy-use permanent systems have been developed, the volume of data available for processing has greatly increased. However, imaging conditions are rarely ideal - rain, cloud, wind and other influences can impact significant proportions of data retrieved. Dealing with imperfect data requires changes to standard processing procedures, and the uncertainty in measurements is significantly increased. Therefore evaluating data quality and adapting processing methods manually is a necessary but time consuming task. Multiple previous works have focussed on automation of processing steps. However, a current limitation is the ability to adapt both processing methods and uncertainty estimations based on the quality of a given retrieval, without user interaction. In this poster we present progress toward detailed, automated quality assessment of UV image data. Computer vision techniques are used to replicate the judgement of an expert human user evaluating the data. This will form a first step toward reliable automation of data processing as a whole, and improve understanding of the uncertainty in flux values derived from this data.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Enhancing Phase Detection of Volcanic Earthquakes Through a Multi-Station Machine Learning Model

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Seismic phase picking is a crucial step in many volcano monitoring workflows. Over the past decade, several deep learning algorithms have been developed for this task and have shown impressive results. However, despite many volcanoes hosting a multi-station network, existing deep learning models for phase picking still process data from each station independently. As a result, these models are 'blind' to the relationships between seismograms from different stations that capture the same underlying event. Unlike these models, human analysts frequently use contextual information from multiple stations to pick phase arrivals at stations where the signal to noise ratio is low, and to rule out spurious signals. Here, I present ongoing work to develop a multi-station deep learning phase picker that takes raw seismograms from multiple stations as input and incorporates context from neighbouring stations to update the probability of phase arrivals at individual stations. The model architecture has been designed using graph layers which allow for a variable number of station recordings as input. This is a practical necessity for scenarios in which a station drops offline or is damaged, and means the model could be used at different volcanoes, irrespective of their network configuration. Using a 14-month dataset from Nabro volcano, Eritrea, acquired following the onset of its VEI4 eruption in 2011, I will present findings on how to best encode and share signal context across stations to optimise model performance, and compare the performance of multi-station models against standard single-station model equivalents.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Extraction of Multimodal Surface Wave Dispersion Curves in Volcanic Area: Case Study on Mt. Ontake, Central Japan

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Over the past quarter-century, ambient noise tomography (ANT) has been proposed for imaging subsurface seismic velocity structures. In ANT, extracting surface wave dispersion curves from the cross-correlation functions (CCFs) of ambient noise is an important process. However, artifacts in the dispersion energy plot and non-uniqueness in the inversion of subsurface structures are notable challenges. To solve these problems, the frequency-Bessel transform (F-J) method and high-resolution linear radon transform (HTLRT) have been developed. However, they have been examined only in flat fields with a scale of several hundred kilometers. To examine their applicability in volcanic regions where steep topography is common, we applied the F-J method to seismic data at Mt. Ontake, central Japan. We used 43 stations within a 50 × 50 km region centered on the summit of Mt. Ontake from January 1 to December 31, 2019. The maximum and average interstation distances were 42.0 km and 12.7 km, respectively. The calculation of the CCFs was successful for multiple components and showed the same tendency as that on flat land. The modified F-J spectrogram shows dispersive energy without cross-artifacts, but the second and third artifacts remain and overtones are unclear. Next, we apply the modified multicomponent F-J method and HTLRT to solve them. More constrained dispersive energy is expected by these processes; however, the effects of the topography and heterogeneity of a volcano should be considered. We plan to perform a simulation using synthetic data, including these conditions, to ensure the practicality of ANT in volcanic areas.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Synthetic aperture radar drone application to study active volcanoes of Iceland

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Volcanoes of Iceland have been studied using numerous remote sensing techniques applied by satellites, aircraft, and drones, resulting in ground deformation analysis, thermal infrared measurements, hyperspectral mapping, etc. Here, we present our results from the first-time application of a synthetic aperture radar (SAR) drone - Explorer RD350 - to study various volcanic landforms in different parts of Iceland. During our expeditions to Iceland in 2024, we collected SAR drone data over i) the areas affected by Sundhnúkur eruptions on Reykjaness Peninsula, including lava flows, crater row, and tectonic features, ii) the 1961 vents of Askja Caldera, iii) Hverir/Námaskarð geothermal area in North Iceland, and iv) rock glaciers at Hekla volcano in South Iceland. Explorer RD350 makes simultaneous acquisitions in three bands (C, L, and P) and operates in three modes (linear, circular, and helical). We used linear flights to obtain high-resolution amplitude images to visually interpret surface features and helical flights to obtain information about subsurface features via the SAR tomography technique. The SAR data acquisitions were accompanied by optical drone surveys (visible and infrared), which let us compare topographic features and thermal anomalies with surface and subsurface features identified in the SAR drone amplitude images. Along with numerous other results, we revealed that the higher intensity areas in the tomographic images of a Sundhnúkur vent likely correspond to higher-density material and represent the conduit of the vent. Additionally, we investigate other potential uses of the SAR drone in volcanology, including rock alteration analysis at certain depths.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Detecting Subtle Deformation on Tropical Volcanic Islands: Advanced InSAR Time Series Techniques for Enhanced Monitoring

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Tropical volcanic islands are often densely vegetated and feature steep, rugged terrains, which can complicate InSAR analysis as they are prone to coherence loss and atmospheric artifacts. Despite these challenges, **AMSTer** software (a fully automatized, incremental, multi-sensor InSAR processor) provides an effective solution for detecting subtle deformation in such environments by integrating multi-sensor data and offering high-resolution, long-term monitoring capabilities. We processed InSAR time series with AMSTer over three volcanic targets: Soufrière de Guadeloupe, Karthala (Comoros), and Piton de la Fournaise (Réunion Island). - **Soufrière de Guadeloupe**: Using Sentinel-1 (S1) data from 2018 to 2024, we detected linear summit inflation and significant south flank sliding, revealing subtle deformation dynamics on this stratovolcano. - **Karthala**: By combining S1 and COSMO-SkyMed (CSK) data, and applying Singular Value Decomposition (SVD) to remove seasonal artifacts, we observed deformation linked to a low overpressure dike intrusion in mid-2022. Despite significant crustal movement, the intrusion failed to trigger an eruption, providing insight into the complex volcanic processes in this region. - **Piton de la Fournaise**: Using ALOS-2 data, we tracked subtle inter-eruptive deformation in 3D, to capture the dynamics of the deeper magma reservoir between eruptions, with implications for eruption forecasting and hazard assessment. AMSTer's ability to process data from multiple satellite platforms (including Sentinel-1, CSK, ALOS-2, and others), along with its fully automated and incremental processing, makes it a powerful tool for overcoming the challenges of monitoring deformation on tropical volcanic islands.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Detecting Volcanic Deformation in Hawaiʻi Using Multimodal Deep Learning Techniques

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InSAR and GNSS are important for volcano monitoring and characterizing subsurface magmatic plumbing systems. Dense GNSS networks exist at many volcanoes throughout the world, and InSAR data are becoming more ubiquitous with each new SAR satellite launched. Machine learning has previously been used to automatically detect when and where deformation is occurring in large volumes of InSAR data. Here, we build upon these techniques by showcasing a multimodal deep learning model that utilizes both InSAR imagery and GNSS timeseries to assess a volcano's deformation state. The model has two independent branches that process each datatype separately: the InSAR branch is a pretrained convolutional neural network (CNN) that is modified to process InSAR data; the GNSS branch is a simpler multi-layer perceptron (MLP) that is trained from scratch. These streams are then combined by averaging their output probabilities. In this manner, each branch can also be used independently. Also, while accuracy is important, we strive to make the reasoning behind the network's decision-making transparent to avoid the "black box" nature of many machine learning models by using integrated gradients backpropagation techniques. We apply this model to Mauna Loa, Hawaiʻi using Sentinel-1 InSAR data and GNSS data from the USGS Hawaii Volcano Observatory, both spanning 2015 to 2024. We chose Mauna Loa as it deforms often and is a very high threat volcano. Our aim is to develop a trustworthy multimodal model that can automatically detect deformation using a diversity of spatiotemporal datasets to assist in monitoring and science efforts.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

From Seismic Signals to Volcanic Processes: Data-Driven Approaches at Piton de la Fournaise

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Seismic earthquakes and tremors recorded in the vicinity of volcanoes capture the signature of multiple volcanic processes such as volcanic edifice deformation, magma motion, degassing, etc. However, the link between the seismic signals and the state of the volcano's plumbing system and its underlying physical processes remains poorly understood. Continuous ground motion recordings provide a comprehensive dataset to analyze the full complexity of ongoing volcanic activity over extended periods. Volcanic seismicity is often characterized by discrete event catalogs based on a priori classification schemes, which may contain significant gaps in time coverage. Here, we explore another approach based on unsupervised machine learning that enables us to discover patterns within continuous datasets without requiring predefined labels. More specifically, we extract statistically significant features of seismic signals using the scattering transform, a type of convolutional neural network, and subsequently apply the Uniform Manifold Approximation and Projection (UMAP) to identify meaningful patterns related to the evolution of volcanic systems and various types of their activity. The active basaltic volcano Piton de la Fournaise on La Réunion, France, with more than 30 eruptions in the past decade recorded by a dense seismic network, provides an ideal data set to test and refine this methodology. We analyze ten years of three-component seismic recordings and compare the results of our analysis with complementary datasets, including earthquake and tremor catalogs, ground deformation measurements, and lava discharge rates.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Automatic assessment of volcanic activity of Hakone volcano, Japan -Introduction of volcanic unrest index and automatic detection of earthquakes-

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In volcanic areas, multiple types of observations, such as seismic, geodetic, and geochemical observations, are applied. At Hakone Volcano in central Japan, our research institute has primarily conducted many observations. At this volcano, we experienced a small phreatic eruption in 2015 and an episode of unrest in 2019. From these events, several issues have been identified, such as how to interpret multiple types of observational data and how to automatically acquire and analyze the data. In order to interpret multiple types of data, we have developed a Volcanic Unrest Index tailored to Hakone Volcano, based on Potter et al. (2015). We assign criteria corresponding to indices 1, 2, 3, and 4 to each type of data, such as the duration of swarm earthquakes, the amount of crustal deformation, and the compositional ratios of volcanic gases. The analysis uses data within a 30-day time window and has been designed to automatically output the results every day by shifting the time window forward by one day. On the other hand, observation data is acquired through manual work, such as on-site measurements of volcanic gas and the picking of earthquake waveforms. Therefore, we are currently developing automatic detection methods for volcanic earthquakes based on the matched filter technique and machine learning. Using these methods, we aim to detect not only volcanic-tectonic earthquakes but also deep low-frequency (or long-period) earthquakes and small earthquakes occurring at very shallow depths.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Low-Cost Photogrammetry Technique That Uses a Locally Defined Coordinate System to Model Meter-Scale Cavities or Vertical Features

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Photogrammetry is a useful technique in geoscience to generate three-dimensional models of geologic targets for detailed quantification. The proposed low-cost alternative relies on a local coordinate system to compensate for the challenge of collecting accurate GPS coordinates. This method is particularly useful to measure vertical surfaces, subsurface cavities, or other features at the meter-scale. Typical photogrammetry methods include the use of an unmanned aerial vehicle or terrestrial LiDAR technology. These methods can be impractical when GPS-based ground control points are challenging to define due to limited access, flight restrictions, or the target feature being underground. The proposed method uses 7.5-centimeter wooden cubes to define a coordinate grid within or around the feature of interest. X, Y, and Z coordinates are defined from an origin cube and photographs are captured then processed in AgiSoft Metashape to generate a digital three-dimensional model. This technique was executed to model three <2-meter diameter lava tubes (MT009, MT011, and MT012) in the 1961 lava flow at Askja, Iceland. The average percent errors of these lava tube models are as low as 5%, demonstrating the efficacy of the method in capturing subsurface cavities with high accuracy. This technique demonstrates an inexpensive approach to digitally model meter-scale geologic targets that are inaccessible. The generated models are proven to yield accurate measurements which enables detailed quantification that doesn't require physical revisitation.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Using Google Earth Engine as a tool for estimating volcanic cloud-top height based on GOES imagery: a case study at the remote Sangay volcano, Ecuador

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Sangay, the most active volcano in the Ecuadorian Andes, has been continuously erupting since the XVII century. During its current eruptive period, which started in 2019, several paroxysmal events with ash columns reaching 8–15 km above sea level have caused regional ash fall, negatively impacting communities and temporarily shutting down Guayaquil International Airport. Here, we evaluate the feasibility of applying a novel Google Earth Engine code to GOES imagery to estimate and track volcanic cloud-top height of various paroxysmal events at Sangay volcano between 2020 and 2024. The dark pixel method was implemented for the cloud-top height estimation. The cloud-top temperature, taken from the 10.3 µm GOES infrared band, is matched to the corresponding atmospheric profile from NOAA's global model, assuming a thermal equilibrium between the cloud-top and the surrounding air in the atmosphere. Moreover, this well-known method was implemented in Google Earth Engine, as this open-source platform offers several advantages, such as enabling online, cloud-based processing of large datasets, providing easy access to both current and archived data, and featuring a user-friendly interface suitable even for non-coding experts. Ash cloud heights obtained through this methodology for paroxysmal events of varying characteristics were compared to Washington VAAC advisories, demonstrating that Google Earth Engine is a powerful tool for rapidly and continuously estimating ash cloud heights and enabling a detailed study of explosive eruptive events. This tool could be easily implemented at Volcano Observatories as an additional method for monitoring erupting volcanoes, providing valuable quantitative information regarding volcanic ash hazards.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Reevaluating the 2008-2009 Yellowstone Lake Seismic Swarm with Deep Learning

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The 2008-09 Yellowstone Lake seismic swarm was one of the most energetic in the last several decades with >800 earthquakes recorded between December 26, 2008 and January 8, 2009 (ANSS Comprehensive Earthquake Catalog, ComCat). While the cause of the swarm is uncertain, its location and coinciding extensional surface deformation hints at magma migration. Recent tomographic imaging suggests that the hypocenters occurred within an area of shear wave speed anomalies of up to 25% slow, suggesting that the swarm was located within a warm magma mush zone. In this study, we investigate the spatial and temporal evolution of the 2008-09 Yellowstone Lake swarm, as well as the spatial relationship between swarm activity and magma storage. In particular, we produced an updated seismicity catalog for the Yellowstone region between December 1, 2008, and January 31, 2009, using the QuakeFlow deep-learning algorithm for event detection and location. Compared to ComCat, our catalog increases the number of events during the swarm period from 811 to 1031 and the number of events during the full cataloged period from 1217 to 3248. Hypocenter relocations were completed with HypoDD, a double-difference algorithm that utilizes the offset between observed and calculated travel times. Updated hypocenter locations confirm that the Yellowstone Lake swarm occurred within the seismic slow zone, primarily in a region where wave speeds are 15-20% slow, consistent with a magma mush or partial melt.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Extracting locations from individual cameras: Single view three-dimensional reconstruction to extract flow velocities from static cameras

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The estimation of flow velocities for volcanic phenomena can provide useful information for further research into flow behaviour and reconstruction of event timelines. However, this estimation can be difficult without a-priori knowledge of an event and noise or availability affects results from some sensors (e.g. infrasound arrays, seismometers). In the post-event analysis of the 9 December 2019 Whakaari pyroclastic surges, we were able to estimate flow velocities by reprojecting webcam images into geographic coordinates using a single webcam and computer vision techniques. The reprojection of single camera images into world coordinates, called 'single-view reconstruction', is vastly more difficult than multi-view (e.g. structure-from-motion) reconstruction. However, provided some information on camera location and geometry of the terrain, we found it was possible in our case through solution of the Perspective-*n*-Point problem. This technique may be applicable to other events with static webcams that are prevalent on many volcanoes, provided appropriate information and camera positioning are available. We demonstrate this through analysis of the Whakaari example, evaluating the accuracy of our solution, provide the code and discuss limitations and constraints to this single view reconstruction.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Constructing eruptive histories at the Alaska Volcano Observatory: a harmonious integration of volcanology, petrology, and statistics

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Constructing eruptive histories for a given volcano or region is paramount in accurately assessing volcanic hazards. A significant portion of this work at the Alaska Volcano Observatory deals with using tephra-fall deposits to identify the sources, frequency, and size of eruptions throughout the geologic record in Alaska. Because of the large number of volcanoes and their similarity in chemical composition, linking tephra deposits to source volcanoes can be an extremely challenging and time-consuming endeavor. Recently, however, significant progress has been made using an applied data science approach for tephra correlations by combining the fields of volcanology, compositional data analysis, petrology, and statistics. Using compositional data analysis techniques, we mitigate many of the pitfalls that commonly plague application of statistical tests to compositional data including unit sum constraints and mathematical artifacts. We then show how we can link geologic units, regardless of their source, using geometric means and the Fligner-Killeen test. A probabilistic assessment of the most likely source volcano is then created using two different approaches: machine learning classifier predictions and minimizing Mahalanobis distances. Variables considered for linking tephras to sources are incompatible trace element ratios commonly used in petrology to discriminate between unique magmatic sources. Finally, we use cooperative game theory to help explain which variables are most important in identifying each volcano and conformal prediction to assign accurate uncertainties to statistical predictions. Combined, these steps allow for the implementation of a robust methodology for assigning volcanic sources to tephra fall deposits, allowing more accurate eruptive histories to be constructed.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Volcanology in the Twittersphere

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The social media service X, formerly and popularly known as Twitter, is a microblogging and social networking service whose users can post, interact with, and re-post messages ("tweets"). Each tweet (object) is associated with an array of data, including a unique identifier, a timestamp, text content, attached images, URLs, and location information. This contribution comprises a multilingual longitudinal study of volcano-centric tweet strings over three years. Tweets containing predefined strings (e.g. "volcanic eruption," "erupción volcánica," or "火山噴火") were crawled and downloaded daily over August 2019–June 2023 using a custom Python script, yielding a dataset of over 12 million tweet objects across 20 languages. To compare datasets with varying data volumes (some languages are much more highly represented on the platform than others), I define a "Tweet anomaly score" α. Spikes in α generally reflect real-world volcanic events, so analysis of the evolution of α over time yields some key insights. For example, the recent Hunga Tonga–Hunga Haʻapai eruption is immediately identifiable in all studied strings: discourse about the eruption transcends national and linguistic boundaries. This and other large or newsworthy eruptions (especially if clustered in time) can bring about a step-change in the amount of online discourse about volcanoes in general. However, analysis also reveals linguistic imbalance: English dominates, even regarding eruptions in countries where English is not the main language. As a result, not all eruptions result in equal online traffic, even if the physical characteristics of the eruptions are themselves similar.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Assessing cloud points co-registration methods efficiency based on UAS images acquired in an active volcanic environment (Stromboli volcano, Italy)

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Active volcanoes are challenging environments to study morphological processes, due to their continuous evolution, unpredictability and limited accessibility. Recent technological developments including rapid photogrammetric surveys conducted with Unoccupied Aircraft Systems (UAS) have provided new opportunities for such studies. However, most of the conventional ways to perform surveys (*e.g.,* automated flights, ground control points) and to post-process data (*e.g.,* Real Time Kinematic, Post Processed Kinematic, multi-epoch co-alignment) cannot be applied or do not provide the same data quality as in more stable environments. More specifically, the co-registration of UAS surveys time-series, crucial to accurately assess the morphological evolution of volcanic edifices, proves challenging and necessitates adjustments in the processing techniques used. In this study, we evaluate multiple post-processing techniques (*e.g.,* multi-epoch co-alignment, manual markers, Iterative Closest Point) to accurately co-register the survey time-series of the Stromboli volcano crater terrace. Data have been acquired during two field campaigns in May 2022 and October 2023, with a volcanic activity generating explosive events every 20 to 30 minutes. Our results show that techniques prevailing in the scientific community, such as the multi-epoch co-alignment, may not be the most effective in this context with an average vertical difference over stable areas of 1.95 +/- 0.29 m. On the other hand, less popular approaches, such as manual markers method, may generate higher accuracy results with an average vertical difference over stable areas of 0.28 +/- 0.1 m. We finally provide a best practices protocol for operators willing to work with photogrammetric time-series in active volcanic environments.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Unravelling the heterogeneous character of porous lava rocks from Fogo Volcano (Azores, Portugal) through experimental data

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This research focuses on the heterogeneity analysis of intermediate composition lavas from the Fogo Volcano (or Água de Pau Volcano, Azores, Portugal) using the through-transmission method, standardised determination of water absorption by capillarity, and X-ray microtomography. Ultrasonic velocities and capillarity absorption were measured along three orthogonal directions in six cubic specimens to assess how pore structure varies and influences rock physics parameters. Unconfined compressive strength (UCS) was determined in three cores from a single cube. The bimodal pore size distribution leads to an anomalous capillary imbibition, with two absorption processes described as additive by the applied Sharp Front model. Capillary-connected porosity (5.07%) is lower than total connected porosity (18.5–20.1%), as gravitational fluid transport dominates due to large pores (>1 mm). P-wave velocities (2802–3208 m/s) are largely insensitive to pore shape, while Vp/Vs ratios (1.76 ± 0.25), dynamic Young's modulus (16.78 ± 3.20 GPa), and Poisson's ratio (0.23 ± 0.11) reflect vesicular textures independent of vesicle orientation. Simulated core permeability (0.7–6.6 mD) decreases with increased tortuosity despite higher connected porosity in some samples. UCS ranges from 15.5 to 36.0 MPa and depends on pore size, shape, orientation to the loading direction, and connected porosity. Failure occurs by tensile splitting, with fractures initiating at pore edges and plagioclase phenocryst borders. While capillarity and Vp/Vs ratios show limited directional variation, vesicle shape and size affect strength and fluid transport mechanisms. These findings highlight the heterogeneous physical characteristics of lavas, providing insights for interpreting field measurements and enhancing volcano stability models.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Satellite monitoring of active volcanoes using Short-Wave Infrared (SWIR) observations

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Satellite observations in the SWIR (short wave infrared) region (1-2.5 μm) were widely exploited in the past to analyze hot targets using ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and TM (Thematic Mapper)/ETM+ (Enhanced Thematic Mapper plus) sensors of the previous Landsat series. The Operational Land Imager (OLI) and the Multispectral Instrument (MSI), respectively onboard Landsat 8/9 and Sentinel 2 satellites, have encouraged the development of new methods capable of better mapping hot targets in daylight conditions, when their identification in the SWIR bands is more challenging. The Normalized Hotspot Indices (NHI) by exploiting SWIR radiances from those sensors enable an accurate analysis, identification and mapping of high-temperature volcanic features (e.g., lava flows/lava lakes). In this study, we present the results achieved using the NHI to investigate and monitor recent volcanic eruptions (e.g., Etna, Kilauea, Mauna Loa, Home Reef) also through Himawari-8 AHI (Advanced Himawari Imager), GOES-R ABI (Advanced Baseline Imager) and Sentinel-3 SLSTR (Sea and Land Surface Temperature Radiometer) data at higher temporal resolution. Results show that daytime/night-time SWIR observations may highly support the monitoring of active volcanoes enabling also the quantitative characterization of volcanic thermal features. In this direction, the NHI algorithm, running operational under the Google Earth Engine (GEE) platform, may provide a relevant contribution to the surveillance of active volcanoes from space.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Volcanic stratigraphy reconstruction using crystal size distribution automated by machine learning

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Volcanic stratigraphy reconstruction is traditionally based on qualitative facies analysis complemented by geochemical analyses. Here we present a new technique based on crystal size distribution to quantitatively fingerprint lavas, shallow intrusions and coarse lava breccias even where moderately altered, and/or complexly tectonized. We built an automated image analysis workflow using machine-learning for crystal segmentation, followed by statistical algorithms to compare and match the size distribution of feldspar and ferromagnesian phenocrysts. The workflow comprises three instance segmentation models for pre-processing the images, automated scale measurement and grain segmentation using Mask RCNN that provide an unbiased and quantitative approach to determine crystal size distribution. This novel technique avoids the laborious and time-consuming task of manual picking by image analysis. We successfully tested this method in the mineralized Cambrian Mt Read Volcanics in Tasmania, Australia. Multiple dacitic bodies could be correlated across several drillholes, and independently validated by bulk-rock chemical analyses of key samples. This volcanic stratigraphy method can be applied to a large variety of igneous rocks and is complementary to geochemical analyses and qualitative crystal content assessment.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Amphibole machine learning thermobarometry and chemometry: a general model for igneous rocks

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Amphibole thermobarometry and chemometry models can provide quantitative information on the geometry and evolution of a broad variety of igneous systems. However, the chemical complexity of amphibole has hindered many previous attempts to calibrate robust, broadly applicable models; the ability of machine learning (ML) to unravel complexities in large datasets makes it a powerful tool for addressing this challenge. Here we develop a new ML amphibole-only thermobarometer and chemometer that incorporates the latest advancements in ML thermobarometry and is trained on a significantly expanded training dataset (>800 experimental amphibole-melt pairs) compared to the ML thermobarometer and chemometer developed by Higgins et al. (2022). Before calibration, this dataset was rigorously filtered using various statistical techniques, a stage often overlooked in earlier ML studies. The model includes both traditional and novel methods to describe uncertainty associated with each pressure (P), temperature (T) and melt composition (X_{melt}) estimate. Additionally, it outputs the experimental amphibole and liquid compositionally closest to each natural amphibole, enabling users to consult the corresponding experimental paper to verify other geochemical features and critically assess the P-T-X_{melt} estimate. Moreover, this allows users to reference the article/s with the best matching experimentally synthesised amphiboles. To validate the model, its performance is compared against widely applied amphibole thermometers and barometers (e.g., the amphibole-plagioclase thermometer and Al-in-hornblende barometer) as well as amphiboles from granites with known emplacement pressures. Finally, we apply our new calibration to amphibole-bearing intrusive fragments from the Lesser Antilles island arc, refining the previously reported P-T-X_{melt} stratification of the crust.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Combining thermodynamic- and machine learning-based thermobarometry

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Over the past few decades, numerous thermodynamic-based and empirical models have been developed to describe mineral compositional changes and mineral-melt exchange reactions. More recently, machine-learning (ML) models have emerged, using only minerals (or melts) and mineral-melt pairs. However, current ML-thermobarometers do not incorporate thermodynamic constraints, relying solely on comparisons between the chemistry of the target phase and experimentally derived compositions. Importantly, these two approaches are not mutually exclusive and, ideally, should be integrated for more robust results. We present the results of preliminary tests designed to evaluate the efficacy of ML-thermobarometers from a thermodynamic perspective. These models were used to compute the melt composition (X_{melt}) in equilibrium with natural clinopyroxene crystals at specific pressures (P) and temperatures (T). Initially, the recovered P-T-X_{melt} data were tested for equilibrium with clinopyroxene by applying a series of thermodynamic equilibrium approaches from the literature. Subsequently, P-T estimates derived from thermodynamic-based and ML-thermobarometers were comparatively evaluated. X_{melt} reconstructed by ML methods is effectively found to be in thermodynamic equilibrium with the natural crystals. However, while P-T estimates from thermodynamic-based thermobarometers are positively correlated according to the thermodynamic properties of melt and crystals, this behavior is less evident using ML- thermobarometers.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Afar triple junction fed by single asymmetric mantle upwelling

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The arrival of upwellings within the mantle from Earths deep interior are commonly observed worldwide, but their role in driving volcanism during continental breakup has long been debated. Given that only a small fraction of Earth's upwellings are situated under continents and a limited number of them are associated with active continental rifting, our understanding of these processes remains incomplete. Here, we investigate the interplay between continental breakup and mantle upwellings using the classic magma-rich continental rifting case study of the Afar triple junction in East Africa. Some studies previously proposed that the region is underlain by mantle upwelling(s), yet others argue for limited involvement of mantle plumes. Several discrete segments of the rift have been studied in terms of magma petrogenesis. However, until now, a paucity of high-precision geochemical data across the broader region has hampered our ability to test the models and evaluate the spatial characteristics and structure of this upwelling in the recent geologic past. Within this study, we present extensive new geochemical and isotopic data spanning the region and integrate these with existing geochemical and geophysical datasets shedding light on the spatial characteristics of the mantle beneath Afar. By combining geophysics and geochemistry using statistical approaches, our multi-disciplinary approach shows that Afar is underlain by a single, asymmetric heterogeneous mantle upwelling. Our findings not only validate the heterogeneous characteristics of mantle upwellings, but demonstrates their susceptibility to the dynamics of the overriding

plates. This integrated approach yields valuable insights into the spatial complexity of mantle upwellings.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

TIRVolcH: a Satellite-Based Volcano Monitoring System for Advancing Global Thermal Data Collection and Processing

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Data collection in hazardous, gas-rich, corrosive, and potentially explosive environments makes continuous ground-based monitoring impractical, often leading to significant gaps or complete lack of data. This challenge is exacerbated in remote and scarcely accessible locations, where satellite-based remote sensing serves as the primary source of volcanic surveillance. While satellite-based thermal remote sensing provides valuable insights into volcano monitoring, the broad spectrum of thermal activity—ranging from weak early indicators of unrest to strong, clearly defined eruption-related signals—presents detection and quantification challenges. As a result, existing systems often fail to consistently track the entire lifecycle of an eruptive event, from early unrest to post-eruptive cooling phases. In this context, we present a wide range of data and applications collected via TIRVolcH, an algorithm designed to detect low-to-high thermal anomalies in volcanic regions. Case studies from various global locations illustrate the algorithm's ability to track and quantify, inter alia, (i) hydrothermal crises at fumarolic fields, (ii) monitoring heating and cooling cycles at volcanic crater lakes, (iii) identifying thermal unrest preceding dome extrusions andor explosive eruptions, (iv) spatially tracking the extent of emplaced lava flows, (v) quantifying flow advancement rates, (vi) tracking long-term lava flow cooling behaviour and, (vii) estimating erupted volumes. We anticipate that TIRVolcH will play a crucial role in detecting and monitoring the full lifecycle of eruptive phenomena, contributing to hazard management, risk reduction, and advancing satellite-based data collection for volcanological applications.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Volcanic cloud detection and retrieval using Machine Learning approach and MSG-SEVIRI data from the 2020-2022 Etna activity

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Volcanic eruptions inject large amounts of particles and gases into the atmosphere. The detection and retrieval of volcanic constituents are crucial to support aviation safety and to quantify their impact on human health, environment and climate. Detection of volcanic clouds represents a key input for retrieval algorithms such as VPR (Volcanic Plume Retrieval) and LUT (Look-Up Tables), which are applied to get information on particles and gas total mass. The detection of volcanic clouds using satellite data is challenging, particularly in the presence of high quantities of water vapor. This latter, in combination with ash particles, can turn into water droplets and ice. This physical phenomenon supposes a limitation for the detection of volcanic clouds. Mount Etna (Italy), between 2020 and 2022, has produced 66 lava fountain events. These events have generated volcanic clouds mixed with ash, ice and SO2, with a top height ranging between 4 and 13 km. In this work a Machine Learning-Based approach to detect and quantify the volcanic clouds generated during these Etna's lava fountain events is carried out. The models have been trained and validated by exploiting a dataset that covers the 66 lava fountains observed by the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) instrument, on board of Meteosat Second Generation (MSG) geostationary satellite, aiming to get insights for the discrimination and quantification of ash, ice, and SO2 in the volcanic clouds. The results are promising for the automatic detection of volcanic clouds and the implementation of retrieval procedures in near-real time.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Rapid LA-ICP-MS measurement of trace elements in volcanic glasses for petrologic monitoring

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Recent eruptions of Hawaiian volcanoes and elsewhere show the usefulness of rapid geochemical analysis for monitoring. This approach relies on making measurements on more rapid timeframes than traditionally associated with geochemical analyses, requiring adjustments to protocols and workflows. We present results from simulated rapid-turnaround laser ablation ICP-MS (LA-ICP-MS) measurements of trace elements in glasses from recent eruptions of Kīlauea volcano, Hawaiʻi. LA-ICP-MS is well suited to rapid analysis due to the speed of individual measurements, analytical versatility, and simplicity of data processing, and can rapidly provide data for 25+ elements to help constrain changes in magma compositions and sources. Measurements used a modified workflow to minimize analysis time. This includes ablating small glass chips placed on double sided-tape, rather than polished epoxy mounts, and data reduction without a separate electron microprobe measurement for the internal standard. Analysis of 14 glass samples from 9 eruptions between1974-2025, in two different sessions, took <5 hours from sample preparation through to the completion of data processing. Over 90% of laser spots returned useable spectra. Results using CaO or TiO_2 as the internal standard are largely comparable to those made on conventional polished samples. Some volatile elements (Si, Pb, Cs, Rb) show greater uncertainties and variability, interpretated as elemental fractionation related to complex sweep gas flow around glass chips. This also precludes the use of SiO_2 as an internal standard. Overall, results support the use of LA-ICP-MS for rapid turnaround measurements to support eruption monitoring and response.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

SSTAR: A user-friendly application to track subtle thermal anomalies at volcanoes

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The past decades have been transformative for thermal monitoring of volcanoes, driven by the launch of new satellites and advancements in spectroscopic surface analysis instruments. These innovations have unveiled diverse thermal responses of volcanic surfaces to subsurface processes, revealing that many eruptions are preceded by various types of thermal anomalies. This underscores the importance of developing new methods to track these anomalies, leveraging existing data and maximizing the potential of current instruments in orbit. To address this need, we introduce *SSTAR: Subtle Surface Thermal Anomalies Recognizer*, a user-friendly application that analyzes subtle thermal unrest (~1 K) across large areas (several km^2) using MODIS satellite data. Building upon the statistical thermal anomaly detection method of Girona et al. (2021), SSTAR analyzes pixel data to track the evolution of thermal anomalies at specific sites and map their spatiotemporal distribution over extensive regions. SSTAR offers several key features, including distinct filtering capabilities for identifying both long-term (years) and short-term (weeks) anomalies with uncertainty quantification using bootstrapping and Monte Carlo approaches. This application provides an interactive interface for seamless data analysis and is standalone, with the added flexibility for Matlab users to customize the scripts to meet specialized needs. We envision SSTAR as a valuable resource for students and researchers investigating subtle thermal anomalies at active volcanoes. Additionally, an upcoming version of SSTAR will support near real-time tracking of subtle thermal unrest, positioning it as a forward-looking tool to advance thermal monitoring of volcanoes in the decades ahead.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Developing and data mining with machine learning a volcanic ash database (VolcAshDB)

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Volcanic ash provides direct evidence of the interior of the volcanoes when they explosively erupt offering unique insights into the state of the volcano and likely transitions in style. Petrologists typically classify ash particles into different types: fragments from the magma driving the eruption (juvenile), older volcanic building material (lithic), weathered or hydrothermally altered material, and free crystals. However, different researchers may identify the same particle in a different class because diagnostic particle features vary across eruptions and volcanoes. Such lack of standardization is a major challenge to compare the ash particles and their interpretations between eruptions and observatories. To address this, we developed a database of volcanic ash particles (VolcAshDB) with ash samples from various magma composition and eruptive styles. Particle data includes a multi-focused, binocular particle image and an array of features that characterize particles' shape, texture and color of 12,044 particles (available at https://volcashdb.ipgp.fr/). We applied machine learning (ML) for automatic particle classification and compared the performance across algorithms of the tree-based family (Decision Trees, Random Forests, Extreme Gradient Boost), deep learning (ResNet, ConvNext) and Vision Transformer (ViT). The ViT achieved the highest accuracy at 93%, and the XGBoost model highlighted the most diagnostic features for classifying particles from different eruptive styles. Through our web-platform, users can browse and obtain visualization summaries of our dataset, and we plan to allow users to contribute to the database to further improve the robustness of our models.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Random Forest classificators for Stromboli volcano (Italy) to detect periods of higher probability of major or paroxysmal eruptions

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Machine Learning (ML) is nowadays one of the most rapidly advancing and widely used techniques to analyse massive sets of data from complex processes, in search of regularities or common and repeated patterns that cannot be recognized by human eye or modelled by analytical formulation. One of the most common application of ML in volcanology, to date, has been in terms of classification of pre-eruptive versus non-eruptive time periods. To this end, time series of Real-Time Seismic Amplitude (RSAM) in different frequency bands have been engineered to define a large set of features characterizing time-periods, and ML methods have been trained and tested for their skill in recognizing in advance the imminence of relevant events, such as eruptions or phreatic explosions. In this contribution we show the preliminary application and results of a ML algorithm called Random Forest (RF) to data from Stromboli volcano, in order to recognize periods of higher probability of occurrence of large explosive events. First, we trained and tested the RF on continuous amplitude RMS measurement data that are available over a period of approximately 8 years, in which about 30 major eruptions and/or paroxysms have occurred. This number of target events (30 events) enabled a better-than-usual testing of the RF skills. Secondly, focussing on a shorter period of time in 2020-2021 during which approximately 8 target events have occurred, we exploited an available dataset of multiparametric time series of seismic, deformation and gas observables, to train and test the performance of a multiparametric RF algorithm.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Machine Learning (ML) methods to address automated mineral segmentation and zonation pattern clustering: application for diffusion chronometry in volcanic rocks

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To capture the information recorded by the different populations of crystals in volcanic rocks, a systematic textural and chemical investigation of all mineral phases is necessary. Such a task is extremely time-consuming. For example, for diffusion chronometry, numerous compositional profiles are required to recover magmatic environments and to get statistically relevant well constrained time scales. To automate the analysis of crystal zoning patterns with further statistical treatment of element 2D distribution maps or 1D concentration profiles, we developed ML methods, such as unsupervised clustering, which allows flexible feature extraction based on multimodal Large Language Modells (mLLMs). The application of mLLMs allows us to analyze a large variety of data types, including BSE images or compositional profiles in minerals. Using the advantages of mLLMs (e.g., leveraging the "one-shot" learning capability), a single example of a relevant feature, such as a specific zoning pattern, can be identified automatically in all mineral phases of a thin section. We applied mLLMs to perform unsupervised clustering of crystals based on their zoning patterns, such as their compositional slopes and plateaus. The approach enables users to formulate in plain text criteria that have to be fulfilled, for example compositional profiles with a given slope or with two compositional plateaus. This approach enables the analysis of large datasets while maintaining the exploratory nature of the task, offering a larger flexibility and scalability compared to traditional methods. Examples illustrating the potential of mLLMs are presented for volcanic rocks of the Klyuchevskoy volcano, Kamchatka.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Introducing Orange-Volcanoes a Visual Tool for Petro-Volcanological Data Analysis: A Case Study in Petrological Volcano Monitoring

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We present Orange-Volcanoes, an extension (add-on) of the open-source platform Orange Data Mining, specifically designed to advance data-driven analysis in petrology, geochemistry, and volcanology. Orange-Volcanoes expands the core capabilities of Orange by integrating tools for: (i) Compositional Data Analysis (CoDA), (ii) cleaning and preprocessing of geochemical and petrological data, and (iii) mineral and liquid thermobarometry. The combination of these tools enables the rapid application of machine learning, statistical analysis, and predictive modeling to large petro-volcanological datasets, supporting visual and interactive data exploration. The platform's visual programming environment fosters collaborative research, ensuring reproducibility and accessibility for scientists, educators, and students without requiring programming skills. The ability to apply diverse statistical and machine learning tools to geochemical data, while interactively visualizing step-by-step results, makes Orange and Orange-Volcanoes valuable assets for managing large multivariate datasets and supporting petrological volcano monitoring. The ability to apply explainable artificial intelligence techniques, such as feature importance and Shapley additive explanations, allows users to better interpret the underlying drivers of geochemical variability, enhancing understanding of magmatic processes. Through case studies, we demonstrate the application of Orange-Volcanoes in clustering geochemical data and conducting petrological assessments. As the volume of geochemical, petrological, and volcanological data grows, this tool facilitates the future integration of data mining and machine learning techniques into scientists' workflows. Orange-Volcanoes represents a significant step toward a transparent, reproducible, and collaborative scientific approach.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Decoding Volcanic Plume Dilution: A Data-Driven Approach to Magmatic Gas Signal Recovery

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A substantial amount of information on the chemical composition of volcanic plumes has been derived from the MultiGAS technique. This method provides high-frequency (1 Hz) and near-real-time measurements, enabling the systematic detection of precursor cyclic changes in the volcanic gas CO_2/SO_2 ratio before paroxysmal eruptions (e.g., at Villarrica, Stromboli, and Etna). However, near-vent deployments are often hindered by hazards such as ballistics, fountaining ejecta, and ash fallout. As the distance between the instrument and the source increases, the volcanic gas signal becomes increasingly diluted in the atmosphere, making it more challenging to resolve. We developed a Python-based routine to model CO_2 and SO_2 concentration time series. Our findings indicate that high-concentration data ($\geq$ 20 ppm SO_2) can be effectively modeled using simple monotonic decreasing functions, where CO_2/SO_2 ratios decrease proportionally with increasing SO_2. From this, two points are identified: (i) an inflection point (x1), where variations in CO_2/SO_2 ratios significantly decrease and mixing of volcanic/atmospheric gases is attenuated; and (ii) a second threshold (x2) beyond which variations in CO_2/SO_2 ratios become statistically insignificant. Preliminary results indicate that this modeling approach can be applied to low-concentration data, where CO_2/SO_2 ratios exhibit similar decreasing trends. Using the program-selected models, we extrapolate the mathematical trends to determine x1 and x2, enabling systematic extraction of the magmatic gas signal while mitigating atmospheric dilution effects. This approach has the potential to enhance the reliability of the MultiGAS as an effective volcano monitoring tool, particularly at volcanoes where hazardous activity precludes instrument deployment near the source.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Integrating space- and ground-based observations for global monitoring of volcanic gas emissions

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Long-term and high-frequency monitoring of volcanic gas emissions is important for tracking changes in volcanic activity and for assessing the impact of volcanism on the environment and the climate system. Observations from satellite-based sensors and ground-based monitoring networks have developed in parallel, particularly in the past 20 years; together, they provide daily, global data on emission rates. However, differences in vertical and cloud sensitivities, and spatial or temporal resolution result in significant uncertainties. This also makes challenging to compare the results from both platforms. We aim to improve the accuracy and consistency of volcanic SO_2 flux measurements by combining satellite-based information from the ESA/Sentinel-5 Precursor Tropospheric Monitoring Instrument (TROPOMI; global, daily, s. 2018) with data from the Network for Observation of Volcanic and Atmospheric Change (NOVAC; 50+ volcanoes, sub-daily, s. 2005), a ground-based network of scanning differential optical absorption spectrometers. Analysis of TROPOMI data is facilitated by the tools of the open-access Volcano Space Observatory, which implements the “disk integration” method for SO_2 flux calculation. These results are compared with daily statistics from NOVAC, which uses a scanning “perimeter” integration, and with independent estimates of annual emissions from the open-access NASA SO_2 Climatology, derived using a “wind-rotation” method. We assess the results obtained using these methods for a selection of volcanoes with varying levels of activity, plume heights, and latitude. A new approach that integrates information from both platforms is proposed, enhancing both the accuracy and consistency of global and decades-long volcanic gas emission datasets.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Measuring topographic change due to volcanic eruptions using multistatic SAR satellites.

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Significant changes to the local topography occur as volcanic edifices build up and/or collapse and lava, tephra and other eruptive products are deposited. Monitoring such changes in topography is crucial to risk assessment and the prediction of further eruptive behaviour. Multistatic Interferometric Synthetic Aperture Radar (InSAR) is a remote sensing modality particularly suited to this task as it allows for the creation of digital elevation models (DEMs) that can accurately map out three-dimensional changes in the topography, regardless of weather conditions and temporal decorrelation caused by volcanic activity. However, few such missions are however currently operational.TanDEM-X has been used for studying a wide range of volcanic activity, such as basaltic lava flows, the formation and destruction of lava domes and related pyroclastic density currents, and subsurface magma withdrawal and intrusion. However, the temporal resolution and data access are limited. Harmony is an upcoming ESA mission scheduled for launch in 2029 that will provide multistatic InSAR capabilities for the measurement of stress and deformation across the cryosphere, the oceans and the solid earth, including monitoring of topographic change due to volcanic eruptions. Operating in a constellation with Sentinel-1, Harmony will providing an open-access, dense time-series of surface elevation models at a temporal interval of 12 days. This presentation will review existing measurements of topographic change at volcanoes from the TanDEM-X mission, and then assess the ability of Harmony to measure topographic change in volcanic conditions.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

The Miniature Multispectral Thermal infrared Camera (MMT-gasCam) for volcanic monitoring: Laboratory calibration and first field data

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The Miniature Multispectral Thermal infrared Camera (MMT-gasCam) for gas retrievals was designed to detect volcanic SO_2, ash, and aerosols from a ground-based platform. The camera system has a long lineage that pairs thermal infrared (TIR) filters with small commercial off-the-shelf TIR camera cores. This camera is housed in a weatherproof tripod-mounted head connected to power and data storage in an external case. The MMT-gasCam expands upon past instrument development by employing two wheels, each housing six filters to greatly improve the spectral resolution. As each wheel spins, the camera continually collects raw image data, which are separated by filter, calibrated to surface radiance, and converted to temperature and emissivity, from which plume species compositions are retrieved. Unlike other TIR-based systems designed for spectral analyses that either have low spectral resolution or are too heavy for rigorous field campaigns, the MMT-gasCam benefits from having a high spatial and spectral resolution and is portable by one person. With this versatility, the camera is deployable at locations either near volcanic vents or from distances of several kilometers to capture the entire plume. Laboratory calibration is performed using a microgroove high-precision blackbody plate that maintains temperatures from 273 to 393 ±0.5 K. Retrievals are conducted by releasing gases in front of the plate at known flow rates. Recent internal structural updates to the camera have made it possible to endure more rigorous field conditions. Here we present the laboratory calibration and validation, as well as initial field-based data collection of the MMT-gasCam.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Enhancing Volcanic Seismic Monitoring of Semeru Volcano Using Data Integration and Automated Workflows

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On December 4, 2021, Semeru Volcano in Indonesia erupted, producing pyroclastic density currents (PDCs), resulted in 51 fatalities, 169 injuries, and 22 missing people. Semeru is primarily monitored using seismic as primary instrumentation, utilizing various seismic methods to perform analyzes, assess, and evaluate volcanic activity. At the time of the eruption, data acquisition, processing, and analysis were conducted separately and lacking integration. This study aims to enhance seismic volcano monitoring methods by integrating seismic data acquisition, governance, and processing into a unified and streamlined system. Improvements in data governance were achieved through standardizing data formats, establishing storage, and implementing a database for data indexing. Specifically, the seismic methods were used are RSAM (Real-time Seismic Amplitude Measurement), MSNoise (Monitoring Seismic Velocity Changes using Ambient Seismic Noise), Seismic Event Clustering, and REDPy (Repeating Earthquake Detector). While MSNoise inherently features a built-in database structure, custom database schema designs were developed for RSAM and REDPy. These three methods were integrated into a single workflow using Apache Airflow. This integration enables real-time monitoring of data availability and completeness, allowing for more effective data quality control. The results of this study demonstrate that integrating seismic data acquisition, storage, governance, and processing significantly improves data quality, analysis, and processing efficiency. This approach has the potential to be adapted for monitoring other volcanoes in Indonesia, improving early warning systems and volcanic hazard assessments.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Exploring Opportunities, Epistemological Challenges, and Risks of Machine Learning in Volcano Science

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Recent advancements in Machine Learning (ML), combined with significant improvements in computational capabilities, have brought substantial changes to scientific research. These developments have impacted numerous scientific fields, including physics, medicine, chemistry, mathematics, neuroscience, biochemistry, materials science, and engineering. In this work, we review the opportunities, epistemological challenges, and potential risks associated with the application of Machine Learning in Earth Sciences, with a particular focus on igneous petrology and volcanology. We emphasize the benefits of Machine Learning, especially in automating tasks, enhancing modeling strategies, and accelerating knowledge discovery. However, the integration of Machine Learning into scientific research also presents significant challenges. Key concerns include understanding what Machine Learning models actually learn, ensuring transparency, reproducibility, and improving model interpretability. These challenges become particularly critical in high-risk contexts such as volcanic hazard assessment, risk mitigation, and crisis management, where reliance on Machine Learning outputs can have profound consequences for human lives. Additionally, we address ethical considerations, such as the potential for over-reliance on Machine Learning models and the broader implications of geopolitical development plans, laws, and regulations in the EU, China, and the United States.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Volcanic tremor and deformation during the 2012-2023 lava fountains at Etna unveiled by high-precision strain signal

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Explosive eruptions mainly consist in the powerful ejection of gas and solid products up to kilometres above the sea level affecting civil aviation and infrastructures. Such eruptions show differences in terms of duration, intensity and amount of emitted products implying different degrees of associated hazard and pointing out that different eruptive styles and magma ascent dynamics can be involved. Magma ascent produces ground deformation and seismic vibration. Deformation at low frequencies (< 0.01 Hz) is typically associated with the withdrawal of magma that supplies the event from depth and captured by tiltmeters and strainmeters. Seismic vibration, recorded as volcanic tremor (> 0.5 Hz), is usually related to the fast interaction between magma and the rock and is detected by seismometers. In this work, we analyzed the signal recorded by Sacks Evertson strainmeters which measure the volumetric deformation of the ground at the highest resolution (10^{-11}) and in a wide frequency band (0 to > 20 Hz) covering both the tiny slow deformation and the volcanic tremor generated by the eruptions. The use of only one sensor allows studying the possible connection between these two processes avoiding the effects of different instrumental responses. We focused on 84 lava fountains occurred at Etna volcano in the period 2012-2023. Machine learning methods were applied on the strain signal to analyze the relationship between deformation, tremor and eruptive style. The comparison between geophysical data, volcanological observations and petrological measurements gave new insights into the eruptive mechanisms involved during explosive eruptions.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Evaluation of a random forest model to forecast paroxysms at Volcán de Fuego, Guatemala

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The high level of activity at persistently active volcanoes, characterised by large numbers of events recorded in geophysical monitoring data, often with emergent onsets and extended durations, calls for statistical and data-driven approaches. Here, we evaluate the performance of a forecasting model applied to seismic data collected by INSIVUMEH's monitoring network at Volcán de Fuego, Guatemala. Fuego displays a background of low-level explosive and effusive activity, punctuated by more intense explosive episodes (called paroxysms) on average two to three times per year, which are frequently accompanied by pyroclastic flows. Due to the difficulty and challenges related to evacuations at Fuego, it is crucial to forecast the onset of a paroxysm as early and with as much confidence as possible. This context motivated our exploration of forecasting models based on machine learning. The selected forecasting model was developed by Dempsey et al. (2020, *Nature Comms 11*) to forecast sudden phreatic explosions at Whakaari volcano (Aotearoa New Zealand). We evaluate the model's performance in the very different context of a persistently active volcano with a magma-filled conduit to shallow levels. The model was first trained using 48-h data windows labelled according to whether or not a paroxysm occurred in the subsequent window, omitting 1 month of data before and after a chosen 'target' eruption. The model's forecasting performance was tested using 5, 7 and 10 labelled eruptions. We describe important differences with the Whakaari context that required special consideration, the conditions under which the model performed best, limitations, and future perspectives.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Reykjanes Peninsula: fires and faults as witnesses of a rifting episode

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As the ongoing rifting episode began, the Reykjanes Peninsula in SW Iceland was deformed at the location of new dikes and eruption sites, affecting the entire peninsula. Our study examines surface deformation along an East-West transect of the peninsula, using a combination of InSAR (Interferometric Synthetic Aperture Radar) time-series, kinematic GNSS (Global Navigation Satellite System) data collected with a vehicle-mounted antenna, and high-resolution drone photogrammetry at selected locations of active faults. This integrative approach provides valuable insights for choosing appropriate surface deformation monitoring techniques during a volcano-tectonic unrest. Our analysis reveals how faults were reactivated and how new fractures formed between 2020 and 2024 by unveiling their strike, vertical offset, normal and shear displacement components. We detect fracture displacement at the centimetre scale and up to meters. The surface expression of fault displacement agrees with seismic moment tensors data at depth, and we highlight multiple NS-oriented faults with a right-lateral kinematic sense of motion. The tectonic stress release represents a critical part of the signal during the early phase of the rifting episode, coinciding with dike intrusions and facilitating magma transport to the surface. We demonstrate the benefits of combining different methods and resolutions to understand the deformation processes on the peninsula. These results contribute to refining monitoring strategies relevant to the broader scientific community.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Machine-learning-based Earthquake Catalog Reveals A Clearer View of the Current Phase of Unrest at Campi Flegrei Caldera

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Artificial intelligence provides an opportunity to fully harness the potential of a highly efficient seismic monitoring network, such as the one installed in the Campi Flegrei caldera following the significant increase in seismicity recorded in 2021. Three years of continuous seismic data were reanalyzed using a machine learning system specifically trained to identify VT earthquakes in a highly anthropized area like Campi Flegrei. This approach increased the manually compiled seismic catalog from around 9,173 to over 46,350 earthquakes, resolving a fine-grained image of the caldera structure. The developed tool aims to mitigate seismic and volcanic risks in the region by enabling the automatic detection of potential earthquake migrations or the activation of previously seismic areas, which could indicate magma movements.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Onset of diking recorded by pressure spikes in geothermal groundwater monitoring wells in Svartsengi geothermal area, SW-Iceland

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On 10-11 November 2023, a 15 km long, 130 M m^3, SW-NE-trending dike was emplaced into the crust, extending from the center of the peninsula, underneath the town of Grindavík and off the south coast of Iceland. This event occurred in the Svartsengi volcanic system, on the Reykjanes Peninsula, SW Iceland, fed by a shallow magma storage domain that has been inflating. This event was captured in real-time by an immediate, real-time sharp spike of >300 kPa in pressure readings in geothermal groundwater monitoring wells of the nearby Svartsengi geothermal system, operated by HS Orka. This was the first time an event like this had ever been captured in real-time using the signal detected by down-borehole pressure sensors. Each of the 9 subsequent, smaller, diking events utilized the pathway established on 10-11 November, with 7 resulting in eruptions. All of them generated distinct rapid pressure increase signals of 20-150 kPa in the monitoring wells. The strength and morphology of each pressure signal correlates directly with the estimated dike volumes, median opening, and location along the November weakness. Detection of the start of a dike propagation, in real-time, has enabled a high degree of temporal and spatial monitoring, and the development of an additional early warning system by HS Orka, used by Veðurstófan and Almannavarnir. This setup will be utilized for future events at this location, but could also be implemented in other locations around the globe where groundwater boreholes exist within or in close proximity to an active volcanic system.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Radionuclides behavior in hydrothermal volcanic systems: Preliminary investigations at high and low gas flux emission sites

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Studies over long periods at many active volcanic systems in the world revealed that radionuclides measurements in volcanic plumes provide useful indications of degassing processes in terms of volume of degassing magma, timescales of magmatic processes, chemical composition and depth of the reservoirs. In this study, we describe the preliminary results obtained from two radiometric surveys carried out between January and April 2024 at Pisciarelli (Campi Flegrei caldera, Italy) and Stephanos crater (Nisyros island, Greece), sites characterized by high and low gas flux emissions, respectively. Radioactivity measurements were collected through a scintillation gamma-ray detector in order to find potential correlations between volcanic gas (i.e., CO2 and H2S) and radionuclides concentrations at ground level and in atmosphere. We provided scans at four different altitudes from the ground, aiming to disentangle the contributions of the radionuclides (i.e., 222Rn, 220Rn, etc.) transported by the gas species diffused in the air from those contained within the rock and soil. Different volumetric profiles and 2D maps of gamma rates and gasses concentration have been plotted considering short (60 seconds) and long (600 seconds) acquisition times in multiple field spots for each scan altitude.

Theme: 3. Volcanic processes

Session 3.1: Innovative Data Collection, Machine Learning, and Processing Methods in Volcanology

Allocated presentation: Poster

Comparing deep learning models for phase picking tasks

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Automating the process of locating an earthquake's hypocentral location and calculating its magnitude is essential to ensure the activation of early seismic warning systems. In volcanic regions, this fact becomes even more significant, as it can also allow the location and characterization of possible magmatic sources and monitor in almost real time the direction and propagation of the fracturing that normally precedes an eruption. Deep learning approaches are showing that it can outperform classical approaches by achieving performance that that rivals humans. However, because recent researches differ in their datasets and evaluation tasks, it is unclear how the various models compare to one another when applied to unknown data. Most models are evaluated on only a single dataset, and their performance on new, different data is hard to predict. This study aims to offer a comparison between five previously published models (BasicPhaseAE, EQTransformer, PhaseNet, PhaseNetLight and GDP) trained with four different datasets (ETHZ, Geofon, Instance, Stead). The data used to test the models in this study belongs to the seismo-volcanic crisis occurring since 2022 on Terceira Island in the Azores archipelago. Here we show that there can exist considerable differences in the same model when trained with a different dataset, even between phases, making the choice for any particular model harder to make. The best performer for P phases was GDP, trained with the Stead dataset, with an F1 score of 79%, and for S phases was Phasenet trained with the Instance dataset with an F1 score of 77%.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk [Invited]

Experimental insights into crystal resorption and growth: significance for mush maturation

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Crystals in volcanic rocks often show internal dissolution surfaces followed by compositionally distinct overgrowths. These resorption-and-overgrowth textures represent sudden changes in magmatic environment (e.g., T, P, X, H_2O). However, to date, unambiguous petrological interpretations of resorption-and-overgrowth textures are impossible because they cannot be confidently attributed to specific magmatic processes. To better understand the significance of resorption textures, experiments are needed that isolate the effects of T, P, X fluctuations on crystal dissolution and growth. Here, we present the results of high-P-T resorption experiments isolating the effect of temperature fluctuations on crystal textures. We nucleated, grew, resorbed, and recrystallised plagioclase crystals in a rhyolitic melt, imposing temperature fluctuations typical for plumbing systems in intermediate arc volcanoes (20–40°C) whilst keeping all other variables constant. The experiments reproduce resorption-and-overgrowth features commonly observed in crystals in magmatic rocks and demonstrate that a single temperature spike can introduce significant textural complexity. Moreover, we find that plagioclase dissolution irreversibly reduces crystal aspect ratios, leading to more equant crystal shapes as the amplitude of temperature fluctuations increases. This suggests that crystals stored in magmatic plumbing systems become more equant when exposed to recurring temperature fluctuations. A compilation of plagioclase crystal shapes in Mount St Helens rocks confirms that crystals with dissolution surfaces show systematically more equant shapes than unresorbed crystals. Since equant crystals lock up at higher crystallinities than tabular ones, our findings imply that a mature mush comprising more equant crystals may be more easily eruptible than an immature mush with more tabular crystals.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Variable genesis, storage, mingling, and decompression of andesitic magma in shallow reservoirs drive contrasting pyroclastic density currents at Volcán de Colima, Mexico

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The andesitic stratocone of Volcán de Colima experienced its last major explosive eruption in July 2015. This eruption began on July 10 with dome-collapse-driven block-and-ash flows, typical of Colima's recent activity, and was followed on July 11 by unprecedented open-vent, hot, scoria-rich pyroclastic density currents (PDCs) with a 10.5 km-runout. We conducted fieldwork, chemical analyses, and microtextural studies (electron-microscopy and x-ray microtomography) on the July 11 deposits to investigate the <20-hour transition between these events. Our results show that dome-collapse rapidly decompressed 1021°C, 2 wt.% H_2O, and 58-59 wt.% SiO_2 andesite at rates of 0.4-1.7 MPa/s from ~2 km-depth, driving magma fragmentation at strain rates of 10^{-3} s^{-1} and generating PDCs with discharge rates of 10^6-10^7 kg/s. Variations in decompression rates produced pulsating PDCs, reflecting heterogeneous andesite rheology influenced by multiple stages of magma genesis, ascent, storage, crystallization, and degassing. Additionally, the andesite mingled with rhyolitic melts from a mush layer at 2-5 km depths, a feature absent during prior large eruptions at Colima (1818 and 1913 Plinian events). Microtextural evidence, particularly well-preserved amphibole phenocryst nuclei from 10-15 km depth and the lack of inelastic strain in banded scoria clasts, suggests brief storage and efficient ascent through the shallow, amphibole-free mush. This mush likely tempered the eruption's explosivity in July 2015.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Eruptive dynamics during open-vent andesitic eruptions retrieved from petrological and componentry analysis of Sangay volcano (Ecuador)

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Constraining the pre-eruptive physical conditions and changes in eruptive dynamics at open-vent volcanoes is a key step of any hazard assessment initiative. Sangay volcano in Ecuador is an active, open-vent andesitic system that exhibited intense eruptive activity since 2019. This activity is characterized by recurrent low- to moderate explosivity eruptions, whose ash fallouts impacted communities across south-central and west-central Ecuador. This study analyzes ash and vesiculated lapilli samples from explosive eruptions between 2020 and 2022 to better understand transitions in eruptive dynamics. Variations in componentry, particle textures and chemical compositions indicate shifts in magma dynamics from Strombolian to violent Strombolian, with progressive sealing of the conduit, triggering larger explosive pulses (e.g., 20 September 2020, 5–6 March 2021). These events involved lateral conduit excavation, transporting accidental, and juvenile components. Subsequent pulses (11 March–7 May 2021) were driven by decompression and hotter gas-rich magmatic recharge, resulting in the fragmentation of low-viscosity magma. Whole-rock geochemical data from 2019–2022 reveal andesitic to basaltic andesitic compositions (56–61 wt.% SiO_2), with an invariable mineral assemblage composed of pl + ol + cpx + opx and Fe-Ti oxides. Geochemical modeling suggests fractional crystallization in a shallow reservoir and thermobarometry analysis places the magmatic system at 10–14 km depth (270–400 MPa). Pre-eruptive conditions include magma temperatures of 1029–1077°C and water contents of 1–2 wt.%. This study enhances our understanding of the eruptive processes of open-vent andesitic volcanoes by linking changes in eruptive dynamics to the petrological evolution of magma.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

In-flight fragmentation dynamics in explosive eruptions of low-viscosity magmas

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Volcanic bombs—coarse fragments of low-viscosity magma ejected during explosive eruptions—offer critical insights into eruptive dynamics and hazards. Traditionally, fragmentation has been attributed to conduit processes; however, our research highlights the significant role of in-flight fragmentation in influencing bomb size, trajectory, and dispersal. By analyzing high-speed, high-resolution videos of eruptions at Tajogaite volcano in La Palma, Canary Islands (fountaining and spattering activity); Mount Etna, Sicily (fountaining activity); and Stromboli, Aeolian Islands (strombolian activity), we identified four distinct in-flight fragmentation mechanisms: (i) inflating fragmentation, i.e. pyroclasts expand and fragment, revealing hotter interiors; (ii) deformation fragmentation, characterized by stretching, bending, and rotation before break-up; (iii) detaching fragmentation, which involves breakage without visible deformation; and (iv) collision fragmentation, resulting from interactions between pyroclasts of varying sizes and velocities. In-flight fragmentation affected from 9% to 48% of the observed bombs. Deformation fragmentation was predominant during Tajogaite fountaining (66%) and Strombolian activity (86%), while collision fragmentation was more common in Tajogaite spattering (72.5%) and Etna fountaining (49%). Within the deformation mode, stretching was the most frequent sub-type, with inflating and detaching fragmentation occurring less often. Drag force plays a pivotal role in in-flight fragmentation by inducing or amplifying velocity gradients within bombs, especially in larger, faster fragments with irregular shapes. This increased drag enhances deformation, localizes stress, and promotes

instabilities that can lead to fragmentation. These findings underscore the importance of in-flight fragmentation in determining pyroclast deposition, particularly in mafic eruptions and provide valuable insights for refining ballistic hazard models and improving interpretations of volcanic deposits.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Decadal patterns of pre-eruptive pressure and temperature at Mt Etna from machine learning thermobarometry

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The identification and study of fluctuations and patterns in the eruptive behavior of volcanoes can provide valuable information to predict future activity as well as understanding the dynamics of an ongoing eruption. Mt Etna, one of the world's most active volcanoes, is a natural laboratory exhibiting frequent volcanic activity with different eruptive styles. This constitutes an ideal framework to investigate eruptive patterns and gather insights on the link between the architecture and magmatic processes of the plumbing system and eruptive dynamics. Here, we apply machine learning thermobarometry and chemometry to minerals and glasses (from the literature and newly acquired analyses) from historical and recent Mt Etna eruptions, spanning from 1651 to 2024. The resulting pressure (P), temperature (T) and melt chemistry (X_{melt}) are compared across different eruptions and correlated with key volcanic parameters such as total erupted volume and duration of the eruptive event. Preliminary results reveal significant differences in pre-eruptive P-T-X_{melt} estimates between eruptive events associated with varying styles and mechanisms. For instance, some eruptions, such as the 1974 event, display a pressure range spanning the entire continental crust, whereas others, like the 1669 eruption, exhibit a more restricted range confined within the crust.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Unravelling the effects of volatile resorption on eruption onset in large silicic systems

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Silicic caldera-forming eruptions are inherently difficult to trigger, as prolonged magma storage heats the crust and buffers the buildup of overpressure. One proposed triggering mechanism involves the exsolution of volatiles that pressurize magma chambers via volume expansion. However, exsolved volatiles also increase magma compressibility, hindering recharge-driven pressurization. Therefore, the role of exsolved volatiles in the growth and stability of large silicic reservoirs remains poorly understood. To address this gap, a study of the Aso caldera (Japan) used volatile partitioning in apatite to track water-saturation levels prior to caldera eruptions, revealing the (partial) loss of exsolved volatiles shortly before the cataclysmic Aso-4 eruption. Using a thermo-mechanical box model, we investigate how recharge-induced pressurization, crystal melting and magma mixing influence water saturation and its subsequent impact on chamber pressurization and eruption timing. Our results show that volatile resorption can occur in silicic systems that are subjected to high magma recharge rates involving drier and hotter magmas. Under these conditions, recharge increases the melt volume fraction of the resident magma through crystal melting and the addition of anhydrous melt, driving the diffusion of exsolved H_2O back into the melt to maintain chemical equilibrium. If the host magma chamber loses all its exsolved volatiles, continuous recharge leads to a faster rate of chamber pressurization due to decreased magma compressibility. This rapid pressurization can trigger an eruption up to 100 years earlier than expected under similar conditions but with a residual exsolved volatile phase, posing significant challenges for assessing eruption risk at such hazardous systems.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Volatile contents and quenching conditions during the 2021-2022 eruption of Hunga volcano, Tonga

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The 2021-2022 eruption of Hunga volcano (Tonga) began with weak Surtseyan phases and culminated in a climactic submarine Plinian explosive event and caldera collapse on 15 January 2022. Here we present new insights into the conditions and depths of magma quenching, as preserved by samples spanning stratigraphic units: i) lapilli and bombs from pre-climactic float pumice rafts (stages 1 and 2; Tongatapu); ii) the first lapilli fall from the climactic event (stage 3; Tongatapu); and iii) dense bombs from subsequent waning activity (stage 10; inner caldera rim). Geochemical compositions were determined using Electron Probe Micro-analysis. Fourier Transform Infrared Spectroscopy (FTIR) was performed for quantification of dissolved volatile concentrations, as well as Micro-Computed Tomography for 3D textural analysis, at the ANSTO Australian synchrotron. Lapilli form three main classes: i) dense glass, ii) dark pumice and iii) light pumice, with breadcrust rinds common. Glass-FTIR results span 0.1-1.8 wt% H2Ot. Secondary hydration of H2Om is negligible for subaerially deposited stage 1-3 and minor for stage 10. Plagioclase rim thermometry (Putirka 2008) indicates final crystallization temperatures of 1100-1150 C. Saturation pressures (MagmaSat; Ghiorso and Gualda, 2015) range from ~0.1-5 MPa for the pre-climactic stages, ~2-12 MPa for the climactic onset, and ~7-15 MPa for the waning stage. Corresponding depths show quenching in confined conditions within the edifice and particle textures suggest that this occurred in contact with external water. Ongoing work includes modelling of 3-phase magma viscosity, as important context for the multidisciplinary study of this enigmatic eruption and potentially common, hazardous eruption style.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Magma ascent dynamics and its control on compositional diversity of volcanism across tectonic settings

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The compositional variability of volcanic rocks in continental settings is generally thought to be related to source melting and/or reservoir processes. However, the modulation effect of ascent dynamics on the composition of erupted magmas remains poorly assessed. Viscosity calculations of data collection for ~90 global volcanoes and numerical modeling suggest that magma eruptibility is influenced by initial magma viscosity at the base of a volcanic conduit rooted in the subvolcanic reservoir, and that ~$10^{6.0\pm0.3}$ Pa s represents a threshold of eruption below which magmas ascend at rates higher than the critical ascent rates of freezing. Rhyolitic melt viscosity in continental rifts/hotspots is one order of magnitude higher than that in continental arcs (~$10^{5.5\pm0.2}$ versus ~$10^{4.5\pm0.2}$ Pa s on average, respectively) due to ~1.5 wt% lower pre-eruptive melt H_2O contents in rifts/hotspots at comparable temperatures. The continental rift/hotspot rhyolitic melts thus cannot accommodate large fractions of phenocrysts for eruption, leading to an abundance of crystal-poor (<~30%) rhyolites and a paucity of volcanic rocks with intermediate bulk-rock composition. In contrast, arc rhyolitic melts with lower viscosity can accommodate higher fractions (up to ~50%) of phenocrysts while still remaining below the viscosity threshold, leading to the common appearance of crystal-rich andesites and dacites (with rhyolitic interstitial melts). Therefore, the rheological threshold acts as a filter on the generation of contrasting volcanic rocks in different tectonic settings, which ultimately arises from the different magmatic H_2O contents.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Analysis of iron oxidation state across explosive and effusive eruption products to determine the behaviour of degassing and fragmentation at Tūhua and Tambora.

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Magma involved in volcanic eruptions undergoes large changes in pressure, temperature, and dissolved volatile concentrations. These changes can induce an evolution of iron oxidation state that in turn affects the viscosity of the magmatic liquid and the propensity for crystallisation, both of which are key controls on whether or not magma will fragment to pyroclasts during eruption. Therefore, iron oxidation state changes may be crucially important in eruption physics, as well as potentially acting as a chemical marker of changes that influence eruption style. However, how and why the iron oxidation state evolves during magma ascent, degassing, and eruption, remains poorly constrained. Here, we examine samples from Tūhua, a pantellerite volcano in New Zealand with a history of both explosive and apparently effusive eruptive products enriched in iron. Through x-ray absorption spectroscopy, Mössbauer spectroscopy and electron microprobe analysis, we measure iron valence states across varied eruption styles as well as at the micro-scale in order to un-pick evidence for different syn-eruptive magmatic processes. Initial work has shown similarity in the bulk Fe^{2+}/Fe^{tot} state of deposits across Tuhua, despite their apparent difference in eruption and degassing style. These analyses are compared with products from the 1815 Tambora eruption, where changes in iron valence between pre- and syn-eruptive conditions (determined by EPMA analysis of melt inclusions) can be linked with significant sulfur degassing.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Sintering of vesiculating and diffusively outgassing pyroclasts in the presence of crystals

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Shifts in the eruptive style are strongly influenced by the evolution of permeable outgassing pathways, such as fractures and interconnected pores. These pathways allow gases to escape the system mitigating pressure buildup, magma buoyancy, and its eruptibility. Our observations at the Mono-Inyo Craters, USA, reveal that conduits are commonly infilled by polydisperse (different sizes) pyroclasts with varying vesicularity and degrees of sintering, a surface-tension driven process that progressively decreases permeability and shuts pathways. Unlike sintering of anhydrous fragmental systems, saturated pyroclasts undergoing sintering may vesiculate and diffusively outgas simultaneously, causing hysteretic volume and rheological changes that can inhibit sintering. Additionally, the starting polydispersivity of the granular pack influences the permeability evolution as systems with lower polydispersivity are more closely packed, favouring droplet-droplet interactions. In natural systems, the presence of crystals will both limit droplet-droplet contacts, but also viscous processes. We posit that the addition of crystals to the pack will thus inhibit sintering kinetics, propping open permeable pathways for a longer time. Here we perform experiments using a polydisperse pack of obsidian fragments mixed with different crystal fractions for varying sintering times. We measure the connected porosity and permeability of the sintered pack at a range of confining pressures. Our results show that as the crystal fraction increases, the sintering efficiency decreases, allowing for the permeable pathways to stay open. We conclude that these results have important implications for the degassing dynamics during volcanic eruptions as fragment-filled fractures are ubiquitous to all silicic volcanic settings.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Talk

Numerical Investigation of Magma Ascent in Volcanic Conduits: A 3D FEM Approach

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Numerical modeling of volcanic processes in three dimensions (3D) presents significant challenges due to the complexity of the phenomena involved. The ascent of magma within volcanic conduits is influenced by several factors, including conduit geometry, magma rheology, and the interactions between physical and chemical processes. Understanding these is crucial for predicting volcanic eruption behavior and mitigating associated risks. This study introduces, to our knowledge, the first comprehensive 3D finite element method (FEM) models for magma ascent in volcanic conduits, developed using COMSOL Multiphysics software. We explore different conduit geometries (circular, elliptical and mixed) and integrate fluid dynamics with thermodynamics for effusive eruptions, and fluid dynamics with elastodynamics for explosive eruptions. The interaction between bubbles, crystals, and magma viscosity is also analyzed, providing insight into the complex dynamics of volcanic flows. Preliminary results show that conduit geometry significantly impacts eruptive behavior. Elliptical and mixed conduits exhibit greater variability in mass eruption rate and fragmentation levels compared to circular ones. For effusive eruptions, the coupling between fluid dynamics and thermodynamics, driven by viscous dissipation, plays a crucial role in magma flow dynamics. In explosive eruptions, the coupling between fluid dynamics and the elastodynamics of surrounding rocks shows minimal influence on magma flow, which remains primarily controlled by magma viscosity. This methodology is applied to the Pomici di Avellino eruption of Somma-Vesuvius, focusing on the magmatic Plinian phase (EU2-EU3). The study highlights the importance of 3D modeling in enhancing the understanding of volcanic processes and improving eruption prediction and risk mitigation strategies.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Increased magma recharge at Sakurajima over the past 500 years

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The rate of magma supply to a subvolcanic reservoir exerts a primary control over volcanic unrest and potentially a forthcoming eruption. While it has been possible to infer changes in supply rate over time scales up to a few decades with the advent of GPS, tiltmeters and satellite interferometry, inferring changes in supply rate over longer timescales remains challenging. In this study, we constrain changes in magma supply rate at Sakurajima (Kyushu Island) over the past 5 centuries using a combination of thermo-mechanical modeling, documented eruption history and textural analyses of pumices. We find that the magma supply rate at Sakurajima has increased by roughly an order of magnitude over the last 500 years and that the bubble content in the magma chamber has increased over time, explaining the changes in eruption volume between the Bunmei (~1470 AD), An-ei (~1780 AD) and Taisho (1914) eruptions.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

A molecular-scale origin of non-Newtonian behavior of silicate melts revealed by time-resolved X-ray diffraction under tension, compression and shear

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Silicate melts exhibit non-Newtonian behavior under high deformation rates. To understand the molecular-scale origin of the non-Newtonian behavior of silicate melts, we have developed the experimental system at the beamline (BL47XU) of SPring-8 (Japan). Using this experimental system, the X-ray diffraction of silicate melts at <~900°C can be obtained every ~100 ms under tension, compression and shear. Our experimental studies revealed that intermediate-range ordering (IRO) of silicate melts changes but short-range ordering (SRO) such as T–O and T–T distances, where T and O represent the T site cations (Si and Al) and oxygen, respectively, show no clear variation under elastic deformation. Both the IRO and SRO indicate no change under the Newtonian regime. The IRO reflects the size of the ring formed by SiO_4 tetrahedra; hence, our results imply that the ring size changes during the elastic deformation of silicate melts. Under tension, the ring becomes large anisotropically. Under compression, the small rings form, which are mechanically strong but energetically unstable. Under shear, the rings are anisotropically deformed, that is, the ring structure is compressed and stretched to the directions of macroscopic stress. In all cases of tension, compression and shear, the degree of elastic deformation controls the occurrence of brittle failure; hence, we propose a stress criterion for magma fragmentation.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

An experimental study of the melting of a magmatic mush by heating from a hot basal intrusion

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Understanding the dynamics of magmatic mushes is essential to gain insight into the spatial and temporal evolution of volcanic plumbing systems. In this context, we study experimentally the heating of a mush caused by a hot basal intrusion. The experimental apparatus is a 8 cm-high and 15 cm-diameter glass cylinder with basal and top margins consisting of two horizontal metal plates, whose temperatures are controlled to create a vertical thermal gradient, and with outer wall covered with heating pads to prevent heat loss. We use two types of polyethylene glycol (PEG) as analogue materials, whose properties enable us to meet scaling requirements. At initial state, the cylinder mean temperature is set to obtain an analogue mush consisting of solid PEG particles (analogue crystals) in liquid PEG (analogue melt). The increase of temperature of the lower plate simulates a hot basal intrusion, and the response of the analogue mush is recorded with a video camera through a narrow lateral vertical window. At an initial particle concentration of about 50 vol.%, the particles in contact with the lower plate melt, thus generating a basal liquid layer whose thickness increases over time as the melting front migrates upwards. Subsequently, the remaining granular bed collapses into the liquid layer while particle melting continues as a result of the heat flux provided by the basal plate. Our study gives insight into the possible mechanisms for the thermal remobilization of a magmatic mush.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Melting of host rocks by a shallow sill intrusion

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In several volcanic areas magma bodies have been accidentally penetrated during drilling operations aimed at supercritical hydrothermal resources. The first such well was drilled in the Krafla geothermal field in 2008–2009. Drilling stopped at a depth of 2,096 meters, and cuttings of fresh rhyolitic glass were retrieved. In the Menengai caldera in Kenya, multiple wells have penetrated syenitic magma located 2 kilometers beneath the caldera floor. In both cases, there was an abrupt transition from solid rock to molten magma, accompanied by an extreme temperature gradient. We have developed a 2D model of two-layered convection (for cases where magma and host rocks have different bulk compositions), based on the Navier–Stokes equations for incompressible magma with temperature- and crystal-content-dependent densities and viscosities in the Boussinesq approximation. The energy equation includes the latent heat release associated with crystallization. Phase diagrams for the magma and host rocks are calculated using the MELTS software. Simulations are performed on multiprocessor clusters using the OpenFOAM package. Both rhyolitic and basaltic magmas can efficiently melt the roof of the sill, forming a convective layer of molten rock with an initially linearly increasing thickness. As the intruded magma cools, convection slows, and the propagation velocity of the melting front decreases. The high-temperature gradient in unmelted rock becomes more uniform once melting ceases. A simplified 1D model, based on effective thermal conductivity, is capable of reproducing the results of 2D simulations with sufficient accuracy. This model allows for parametric studies of magma-rock evolution with reduced computational demands.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Numerical model of two-phase magma flow with bubble coalescence

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We introduce bubble coalescence into a recent conduit flow model that ensures the conservation of mass and volatile species and the dissipation of total energy. It extends the capability of this two-phase (gas and silicate melt) model to simulate some eruptive regimes (e.g., Strombolian) that are controlled by coalescence processes, which can help us to better understand these eruptive dynamics. Using kinetic theory, which tracks the number of bubbles in a microscopic volume of magma, we relax the assumption of a constant bubble number density and determine how to introduce bubble coalescence at a microscopic level. We then obtain a macroscopic description of coalescence that is compatible with the original, averaged two-phase flow model. While this original model has eight transport equations on eight unknowns (gas volume fraction and density, dissolved water content, liquid pressure, and the velocity and temperature of both phases), we obtain two more transport equations for bubble radius and bubble number density, respectively. We establish the energy balance of our updated model and find how bubble coalescence contributes to the dissipation of total energy. Finally, we solve our new system numerically with different rates of coalescence and compare the numerical outputs to those of the model without bubble coalescence.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

A conduit model coupling two-phase magma flow with gas chemistry

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Conduit flow models have long produced outputs of total gas content, which often consists of only H_2O. Such outputs are notoriously difficult to relate to natural data because gas measurements are mostly done on species, such as SO_2, that are neglected by conduit flow models. This gap introduces large uncertainties when trying to match model outputs and natural data, which in turn weaken the model capability to explain crucial aspects of eruptive dynamics. We present the coupling of a chemical model of degassing with a two-phase conduit flow model. The initial chemical model, D-Compress, calculates the equilibrium composition of volatiles in the CSHO system of a degassing parcel of magma. We extended D-Compress to address disequilibrium degassing so that the rate of degassing is controlled by a combination of volatile diffusion and decompression rate. We coupled this chemical disequilibrium model to a recent two-phase conduit flow model that ensures strict conservation of mass and volatile species. Such coupling enables us to simulate the combined effects of diffusion-limited exsolution of volatiles and those of outgassing. Our coupled model thus takes into account both the migration and mixing of gas through the permeable bubble network and the changes of gas composition due to volatile exoslution. Such coupling opens the full gamut of behaviors lying between the two end-member scenarios of closed- and open-system degassing. Preliminary results show how the gas emitted at the vent changes its composition (H_2O, SO_2, H_2S, CO, and CO_2) during a typical transition from effusive to explosive behavior.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Experimental simulation of diktytaxitic groundmass formation

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Diktytaxitic texture, a groundmass containing abundant angular interstitial cavities between plagioclase laths, is commonly observed in lava dome interior, volcanic necks, and volcanic ash particles of a wide range of compositions, from basaltic to dacitic. Diktytaxitic texture has particular volcanological significance in eruption explosivity because lava consisting of such cavities is permeable and, therefore, expected to inhibit explosion attributable to late-stage volatile exsolution. However, the exact pressure and temperature conditions, besides the formation rate, remain poorly understood. With these parameters, the source and timing of volcanic ash production would also be clarified. In this context, Sakurai et al. (2024, Contrib. Mineral. Petrol.) experimentally simulated diktytaxitic texture using bulk andesitic magma with rhyolitic glass. They reported that diktytaxitic texture can be produced under water-saturated, near-solidus conditions (10–20 MPa and 850°C, which is within ± ~10 MPa and ± ~20°C of the solidus) in 4–8 days, along with condensation of vapor-phase minerals such as cristobalite and alkali feldspar. These reactions occurred via partial evaporation of the supercooled melt as a result of the system selecting the fastest crystallization pathway. The pressure and temperature conditions obtained are consistent with the common natural occurrence of diktytaxitic texture. The previously proposed mechanisms of halogen-induced corrosion or melt segregation by gas-driven filter pressing are not particularly necessary. These findings constrain the outgassing of lava domes and shallow magma intrusions and provide new insights into the final stages of hydrous magma crystallization on Earth.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

An experimental assessment of plagioclase shape as a proxy for mush solidification timescales

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Crystal sizes and shapes offer insights into magmatic and volcanic timescales. While studies have linked plagioclase aspect ratios to crystallization time in igneous intrusions (e.g., Holness, 2014), experimental validation under slow cooling rates and high crystal fractions remains limited. A causative mechanism remains lacking – specifically, the role of crystal impingement in shaping plagioclase morphology is poorly understood. We conducted high-temperature, high-pressure experiments on anhydrous basalt compositions to simulate slow cooling ($\Delta T/\Delta t$ = 0.8°C/hr) and high crystal fractions (ϕ = 0.65), conditions representative of igneous intrusions. We measured plagioclase crystal shapes from BSE images and processed the length/width data using *ShapeCalc* [2]. Additionally, EBSD enabled examination of crystallographic growth relationships, while reanalysis of mafic dyke samples (Holness 2014;2017) allowed comparison of experimental and natural timescales. Our results show that in crystal-poor experiments, plagioclase aspect ratio correlates with crystallisation time, consistent with natural samples. This relationship reflects anisotropic growth mechanisms across crystallographic axes. However, in crystal-rich experiments, impingement of the c- and a-axes reduces aspect ratios, deviating from predictions under uninhibited growth. Modelling anisotropic growth with limited c- and a-axis dimensions reproduces these shapes, highlighting the impact of crystal impingement. These findings have important implications for interpreting magmatic solidification timescales using empirical relationships. By quantifying how crystal impingement influences plagioclase aspect ratios, we refine our understanding of when crystal shape can reliably indicate crystallization time in igneous intrusions and lava flow interiors.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

From source to surface: Explosivity of peralkaline magmas investigated through the Rungwe Pumice Eruption (Tanzania) case study

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Magma explosivity is primarily influenced by a combination of pre-eruptive conditions inherited at the storage levels and conduit dynamics (magma ascent style and degassing efficiency), both of which impact the physiochemical magma state. In peralkaline magmas (agpaitic index>1), the depolymerisation effect of excess alkalis lowers melt viscosity for a given temperature and strain rate; therefore, such magmas should favour less explosive behaviour than their calc-alkaline counterparts at equivalent silica contents. In the East African Rift, several peralkaline volcanoes display extensive geological evidence of highly explosive eruptions interspersed by lava effusion, raising questions about the factors regulating eruptive behaviour. To investigate the controls on peralkaline explosivity, this study focuses on the 4 ka Rungwe Pumice (Tanzania) Plinian eruption. We integrated a range of geochemical (FTIR, Raman, EPMA) and imaging techniques (2D/3D textural analysis) to reconstruct the magma evolution, from pre-eruptive storage to syn-eruptive ascent and fragmentation. Our results describe an evolved magmatic body stored at 2–5 km depth, close to volatile saturation. Destabilisation of the shallow magma by gas sparging from deeper reservoir(s) likely triggered rapid magma ascent within the conduit (1-2 MPa s^{-1}). Delayed homogeneous bubble nucleation drastically changed magma's rheology at shallow depths. The limited timescales for bubble growth inhibited the development of permeable pathways, preventing efficient volatile degassing, leading to coupling between the gas and magma phases. Ultimately, high strain rates lead to brittle fragmentation, driving explosive activity. These findings highlight the complex interplay between pre-eruptive conditions and conduit dynamics in controlling the explosivity of peralkaline magmas.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

The impact of recurrence time on magmatic systems response to repeated edifice collapse.

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Understanding how a volcano responds to edifice collapse is important for forecasting post-failure changes in eruptive behaviour and associated hazards. At Mt. Taranaki, two collapse events occurred in close succession emplacing the 27.3ka Ngaere (5.85km^3) and 24.8ka Pungarehu (7.5km^3) debris-avalanche deposits to the east and west, respectively. This period in Mt. Taranaki's history was characterised by an increase in large explosive eruptions with at least 28 subplinian events comprising ~3 km^3 of material recorded in the Poto and Paetahi tephra formations. Using 3D Micro-Tomography and geochemical analyses of pumice clasts from these formations, we investigated changes in the magmatic system throughout two collapse and regrowth cycles. Whole-rock compositions revealed an overall trend towards more evolved compositions over time. Bubble texture analysis showed that pyroclasts were dominated by small bubbles (2.7x10^{-7} mm^3) and high vesicle number densities (VND). A clear magmatic response to the sudden decompression associated with the Ngaere collapse is reflected in a decrease in VND (from 1.53x10^{16} to 9.76x10^{15} cm^{-3}) and an increase in MgO (from 4.06 to 4.55 wt.%), suggesting that the change in lithostatic pressure allowed primitive melts to ascend without impediment. This increased the eruptive frequency, partially rebuilding Mt. Taranaki before the Pungarehu collapse removed the opposite portion of the pre-Ngaere edifice 2,500 years later. However, no systematic response to decompression was observed with a gradual compositional evolution (from 3.62 to 3.14wt.% MgO) and increase in VND (from 1.15x10^{16} to 1.29x10^{16} cm^{-3}), highlighting the influence of pre-failure edifice height/loading on the magmatic response to collapse.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Oriented flow textures of magma mingling and mixing within a dyke: the basaltic-rhyolitic Streitishvarf composite dyke, Eastern Iceland

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Studying how magma flows in dykes can help with understanding how dykes transport magma vertically and laterally through the crust and up to the surface. The ~26-30 m wide Streitishvarf composite dyke (10.7 ± 0.2 Ma) in eastern Iceland exhibits macroscopic flow indicators where visually distinct, elongate mafic enclaves (<1 cm – 1 m) are distributed through the felsic core (~10 m wide). The flow within the dyke and the magma interactions are studied at three sites along the dyke, spanning a horizontal distance of ~15 km and ~700 m of vertical distance. We collected photographs for enclave shape and distribution analyses and oriented hand samples for petrographic texture and mineralogy analyses. Our results show that in the south (deeper exposure), the enclaves in the felsic core are aligned sub-parallel to the strike of the dyke but are randomly oriented towards the dyke centre. This indicates the final preserved flow may have been more turbulent towards the centre. Towards the north (shallower depth), the enclaves are aligned sub-perpendicular to the dyke strike. At the microscale, the shape elongation of the feldspar crystals in the felsic core are of similar strike to the macroscale enclaves at each site. This indicates that the macroscale flow indicators are representative of the microscale flow texture. The mineral assemblages reveal magma mingling and mixing at the microscale throughout the samples. We discuss our results in terms of previous magnetic fabric analysis work at this dyke, magma recharge, and magma flow in dykes.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Mechanical controls on fluid flow in healed magmas: Insights from natural and experimental investigation

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The evolution of permeable pathways in magmas is poorly constrained and, as such, our understanding of how pressure may build in the conduit, limiting our ability to accurately forecast what might happen next. Here we focus on understanding how magma healing between two immiscible, yet co-erupted magmas may influence eruptive dynamics. We study the Mono-Inyo domes, in Long Valley caldera, USA that show healed contacts between two physically and mechanically different magmas (fully crystalline dacite vs. aphyric obsidian). These 2 endmembers show a substantial difference in porosity but with high permeabilities that are controlled by the presence of fractures at multiple scales. Healed contacts display a wider response range to increasing confinement than the endmember samples, suggesting a greater variability in the geometry of permeable pathways. Microstructural analysis further reveals undulating contact interfaces crosscut by micro-fractures, suggesting a complex mechanical and cooling history. We then conduct healing experiments in a biaxial press, where we 1) Axially force two glass rods against each other at temperatures above Tg; 2) control simple shear rates and distances to investigate healing kinetics and the geometry of the resulting contact. We show that the healing kinetics remain controlled by a wetting phase followed by a diffusion dominated phase but that the healing efficiency may be influenced by the shear rate. We finally show that the geometry of the healed contact is strongly influenced by both rate and distance. Our results highlight how shear plays a crucial role in closing permeable pathways in volcanic conduits.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Multiple mush generations provide insight into the longevity of open conduit basaltic volcanoes

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Investigating the dynamics and timescales of magmatic processes in open-conduit basaltic volcanoes is crucial for improving our understanding of explosive eruptions and better assessing volcanic hazards. Among these processes, the role of mush disaggregation and remobilisation within the plumbing system remains rather underexplored. This study examines the longevity and dynamics of the mush system beneath Stromboli volcano (Aeolian Islands, Southern Italy), whose persistent activity results from variable degrees of interaction between different magmatic components. The complex zoning patterns of plagioclase phenocrysts from 2003-2021 eruptions have been interrogated by combining in-situ Sr isotope compositions, thermometric modelling, and Mg diffusion chronometry. Our findings shed new light on the physicochemical changes within the plumbing system, the timescales of crystal residence in the shallow reservoir, and the timing of magma recharge events. The response of plagioclase to magma-mush dynamics is rapid during violent explosions but more sluggish during normal activity. Sr isotope heterogeneities in plagioclase reveal that multiple mush generations at Stromboli have been active over millennia, with remobilisation events and crystal recycling driven by mafic magma recharges from depth. This is further supported by a complementary in-situ investigation of clinopyroxene phenocryst cores. A previously unseen, prehistoric, highly radiogenic mush has been actively remobilised in recent years, pointing out that older components of open-conduit basaltic systems may persist longer than previously hypothesised.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Magma ascent processes during the 1977 eruption of Usu volcano inferred from petrological and experimental studies

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Magma discharge rates during repeated explosive eruptions often show variation. The discharge rate is expected to be controlled by magma ascent processes and the condition of the magma reservoir; however, their evolution during repeated explosive eruptions is poorly understood. In this study, we petrologically investigated the magma ascent processes during the 1977 eruption of Usu volcano, which included four sub-plinian eruptions and showed variation in the discharge rate. The water contents of the melt inclusions in the first sub-Plinian eruption indicate a pressure of 100–125 MPa with the assumption of water saturation. The minimum water content gradually decreased from the second to the fourth sub-Plinian eruptions. This means that the magma stagnated at shallow parts of the conduit before the eruption and the depth became shallower. The crystal size distributions of plagioclase microlite show large variations in small size (<1 μm); these small crystals are inferred to crystallize at low pressure (<40 MPa), confirmed by decompression experiments. Based on these observations, we infer the following scenario: the magma in the first sub-Plinian eruption ascended from the magma reservoir at a depth of ~4km; the magma stagnated at a shallow conduit after the first sub-Plinian eruption and then the stagnated magma ascended to the surface during the second to the fourth sub-Plinian eruptions with the gradual ascent of the magma head in the conduit. The quantitative relationship between the discharge rate and magma plumbing system will be investigated in future studies.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Transient numerical conduit model of magma ascent for explosive basaltic eruptions

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Basaltic volcanism is the most common form of volcanism on Earth. Basaltic volcanoes are capable of promoting different eruptive styles, from relatively gentle effusive eruptions generating lava flows, to highly hazardous explosive eruptions, in which large volumes of fragmented magma and volcanic gases are ejected high into the atmosphere. The hazards associated with effusive and explosive eruptions differ, particularly in relation to the timescales, volumes of magma ejected and energy associated with these activities. During basaltic eruptions, rapid and unpredictable transitions between the two regimes may occur, posing a real challenge to policymakers tasked with mitigating the risks associated with basaltic eruptions. In order to investigate the evolution of magma ascent dynamics through time at basaltic volcanoes and possible transitions in eruptive style, we developed a 1D transient numerical model of magma ascent in volcanic conduits. This model is able to solve for the main volcanic processes occurring during magma ascent, such as non-equilibrium crystallisation, non-equilibrium exsolution, temperature and rheological variations, permeability development and outgassing, and magma fragmentation. As test case scenarios, we considered two well-known, highly explosive basaltic eruptions: the Etna 122 BC Plinian eruption and the Masaya Triple Layer Plinian eruption. We used this model to investigate the evolution of magma ascent dynamics and eruptive style resulting from a sudden decompression at the conduit vent (for example due to a partial collapse of the volcanic edifice), or due to a perturbation of thermodynamic conditions within the magma storage region.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

A volcanic bomb as a natural laboratory: insights on melt evolution driven by swift crystallization kinetics during the 2022 Hunga eruption, Tonga

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The 15 January 2022 Hunga eruption was globally impactful, partly due to its submarine setting. This setting also allowed the rapid chilling of pyroclastics and unique insights into natural crystallization dynamics. Using chemical and textural gradients in a zoned Hunga volcanic bomb dredged from the inner submarine caldera, we infer crystallization kinetics and apply thermal modelling to reconstruct cooling history. From bomb rim to core, increasing microlite crystallization drove progressive groundmass glass composition from low-Si andesite to high-Si dacite, closely reproducing compositional variations within tephra from the entire eruptive sequence. This reflects extremely rapid crystallization kinetics, indicated by increasing degrees of chemical and textural disequilibrium of clinopyroxene and plagioclase microlites towards the bomb interior. Swift kinetics are also shown by high crystal growth rates resulting from interaction with water. Our results demonstrate that crystallization processes far outside equilibrium conditions have a pivotal role in driving post-fragmentation melt evolution. These suggest caution must be applied when applying experimentally-derived crystal growth rates to natural cooling processes, as well as interpreting glass compositional variations in terms of liquid lines of descent, and selecting appropriate glass shards for distal tephra identification studies.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Early evolution of the Palaeogene Mull volcano: An integrated volcanological and geochemical approach

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The British Palaeogene Igneous Province (BPIP) has long been an area of interest, both for British volcanology and in the context of the early opening of the North Atlantic. Previous work has focused on the Mull lavas (e.g. [4]) and other BPIP igneous centres, such as Arran [2],[3]. However, since the Mull Memoir was published by Bailey et. al. [1], little research has been conducted on the early evolution of the Mull central complex, the focus of this study. During fieldwork, stratigraphic relationships between intrusive and extrusive deposits have been examined in detail, and new models have been developed for the caldera infill sequence. These models detail a change from basaltic to silicic activity and evidence at least two stages of caldera collapse. Major and trace element analysis elucidate processes such as magma mixing and crustal contamination and determine links between sub-surface magma conduits and erupted deposits. Geochemical fingerprinting is used to investigate the nature of the basement rocks, through which magmas have evolved. An updated volcanological and petrological model is presented of the early evolution of the Mull central complex. The results of this study expand our understanding of the BPIP and have implications for our understanding of explosive volcanism, particularly in young and evolving environments. [1] Bailey, E.B. et.al. (1924) "Tertiary and Post-tertiary Geology of Mull, Loch Aline and Oban", British Geological Survey [2] Gooday, R.J. et.al. (2018) Bulletin of Volcanology 80:70 [3] Gooday, R.J. (2024) Lithos 488-489, 107789 [4] Kerr, A.C. (1999) Journal of Petrology 40:6. pp.873-908

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Volcanic carbonatites: reconstructing the sodium content through experimentally determined apatite-carbonatite melt partition coefficients

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Magmatic carbonatites occur in 454 locations, of which 113 have volcanic carbonatites (mostly breccia, agglomerates and lapilli tuffs). Over the last decades, carbonatites have been intensively studied to understand economic-grade REE mineralizations and the role of carbon and other volatiles in the deep Earth cycle. Yet the true composition of carbonatite melts remains challenging to constrain due to the cumulative nature of plutonic occurrences and the rapid alteration of volcanic ones. Oldoinyo Lengai, the only active carbonatite volcano, erupts lavas with 31-35 wt.% Na_2O, contrasting the 112 fossil volcanic occurrences, which are alkali-poor (median at 0.22 wt.%), likely due to alteration of Na-rich carbonates to calcite, a process that completes at Oldoinyo Lengai within years (ashes) to hundreds of years (dikes). Further, alkalis plays a key role for the unmixing of carbonatite melts from CO_2-bearing alkaline silicate melts and are equally important for transport of REE in alkali-rich fluids. This study determines sodium partition coefficients between apatite and carbonatite melt ($D_{Na}^{apatite/carbonatite}$) to assess the original magmatic Na-content of carbonatites, experiments being conducted at sub-volcanic conditions (200 MPa, 850-1100°C). Results for REE-free compositions yield that the Na_2O-poor (0.2-0.4 wt.%) apatites observed in volcanic carbonatites were in equilibrium with sodic carbonatite melts with 20-28 wt.% Na_2O. Yet, REE may enhance the compatibility of sodium in apatite through the coupled substitution $REE^{3+} + Na^{+} = 2\ Ca^{2+}$, and hence increase $D_{Na}^{apatite/carbonatite}$, the above Na_2O-range might thus represent maximum values; experiments on the influence of REE are under way.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Pyroclast microtextures reveal complex fragmentation history in mafic magmas (Cumbre Vieja, Stromboli, Etna, et al.)

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Magma fragmentation is a key driver of explosive volcanic eruptions. Fragmentation is often simplified as a single process occurring at some well-defined interval in time and space (e.g., the often-invoked ‘fragmentation depth’), but mounting experimental, observational, and textural evidence is now uncovering a more complex picture. Here, we present an ensemble of textural evidence from mafic pyroclasts illustrating the complexity of magma fragmentation during a range of explosive activities. Angular to smooth contours of pyroclasts from the same deposit indicate fragmentation both before and after quenching, with transitional features witnessing fragmentation at the fragile-viscous boundary. Multiple fragmentation events are revealed by the incorporation and re-fragmentation of pyroclast-in-pyroclast. Broken crystals within intact glass reveal the passage of brittle cracks through the magma and their subsequent viscous healing. Crack healing and agglutination of clasts are testified by the formation of sutures, marked by the presence of iron-rich and micro-oxides surfaces. A quantification of these features, performed by Focused Ion Beam Scanning Electron Microscopy and X-ray microtomography, reveals that: i) all these features are common to all study volcanoes; ii) abundance of broken crystals and angular contours increases in parallel; iii) broken crystals are more abundant in finer (ash-sized) pyroclasts; and iv) different eruption styles do not result in obvious textural changes. All these evidences point to a fragmentation history that is always complex spatially and temporally, involving magma at variable temperature, vesicularity and crystallinity, and controlled by both viscous and brittle processes of repeated fracturing, healing, welding, and re-fracturing.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

The origin of maars at the type locality Eifel (Germany): H2O or CO2?

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Maar deposits of the late glacial iconoclastic Pulvermaar (PM) at the type locality Eifel (Germany) are interpreted to have been initiated pyroclastically at midcrustal depth. Cognate mafic nodules (amphibole, phlogopite, clinopyroxene, apatite and minor olivine) up to 35 cm in diameter, and accompanying metamorphic nodules, are mantled by melilite nephelinite crusts. Nodules are probably derived from an almost fully crystallized intrusion, and gneiss carapace, respectively. Fluid inclusion barometry of the igneous nodules indicate depths of about 20 km, corresponding to the Conrad discontinuity. Replenishment of CO_2-rich melilite nephelinite magma fragmented, abraded and rounded cognate and metamorphic rocks at depth. Rounded nodules were covered by compositionally identical lava rinds up to 3 cm thick consisting of minute sub-mm lava spheres interpreted to have formed by fluidized CO_2-rich magma spray. Subrounded melilite-nephelinite lava pellets up to 5 cm in diameter, make up >50 vol.% in the bedded upper 8 m maar deposit. Tightly welded melilite nephelinite agglutinates inside the PM crater represent syn-eruptive lava fountains. CO_2-jetting probably transported the nodule and pellet cargo at 7km/h to the surface, and was strongly enriched in Devonian sandstone and slate clasts during conduit formation. The nearby melilite nephelinite Daun maar cluster contain similar nodules and pellets. High CO_2-concentration is indicated by the magma composition and by fragments of carbonatite consisting of alkali feldspar intergrown with carbonate in several maar cluster deposits. CO_2 is regarded as the dominant factor inducing maar-explosions in these Eifel maars, as in silica-undersaturated, ultramafic and carbonatitic volcanic fields elsewhere.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Numerical modelling of cooling magmatic bodies. Application to Krafla volcano.

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We aim to simulate the dynamics of shallow magmatic bodies while cooling. In order to do so we use, and further develop, GALES (Garg and Papale, Frontiers in Earth Sciences 2022), a numerical simulation software that solves the 4D dynamics of multi-component fluids. Krafla case serves as a perfect example: in 2009, the IDDP-1 drilling inside the Krafla caldera got stuck at 2.1 km, retrieving quenched glass cuttings. I had drilled into an undetected rhyolitic magma body had been drilled. This body stood without apparent signs of crystallisation at the rooftop, opposing the most common belief that magmatic bodies at shallow depths should present a mushy region adjacent to the body's walls. We perform 2D numerical simulations of the thermo-fluid dynamics of a magma of the characteristics of the one encountered under Krafla, assuming thermodynamic equilibrium in a sill-like, disk-shaped body situated at 2.1 km depth. The properties density, heat capacities, single-phase and multiphase non-Newtonian viscosity, thermal conductivity, and compressibility, are locally computed as a function of pressure, temperature, phase distribution and composition. Early results show a strong influence of the volatile phase on the bulk properties, especially density. This translates in the development of small, rising plumes from the bottom, composed of crystals and exsolved gas. Results allow a first evaluation of the conditions under which a crystal mush can form and be stable close to the roof and margins of a shallow magmatic intrusion, and an estimation of the lifespan of a cooling magmatic body of these characteristics.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Constraining pre- and syn-eruptive conditions and processes of the Montagnone eruptive sequence (Ischia, Italy): Implications for transitions in eruptive style in trachytic magmatic systems

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Over the last 10 ka, the eastern sector of Ischia island has experienced volcanic eruptions with a wide range of eruptive styles. Since this area is densely populated, volcanic risk is high, making quantitative insights on how pre-eruptive conditions could control eruptive styles essential for future risk mitigation strategies. We aim to understand how pre-eruptive conditions control such variations in eruptive styles. The Montagnone eruptive sequence (2.4-0.9 ka) is characterised by homogeneous trachytic magma compositions and identical mineral assemblages throughout its eruptions. This eruptive sequence shows transitions in eruptive styles, ranging from lava dome formation to sub-Plinian eruptions. In this work, we analyse the textures and chemical compositions of the juvenile fragments and mineral phases from the Montagnone sequence. Clinopyroxene and sanidine crystals record the remobilization of a cold crystal mush preceding the onset of effusive eruptions. This remobilization facilitated the formation of large amounts of phenocrysts, promoting outgassing and ultimately leading to the formation of a lava dome. In contrast, pumices produced during explosive eruptions are phenocryst-poor, devoid of microlites, and rich in vesicles, suggesting limited outgassing during these events. Notably, clinopyroxene phenocrysts exhibit homogeneous rim compositions (Mg# 73-77) throughout the eruptive sequence. Clinopyroxene–liquid thermometry yields pre-eruptive temperatures of 950-970°C for all the eruptions, indicating that this pre-eruptive parameter was not a primary factor controlling the transition between effusive and explosive events. Instead, pre- and syn-eruptive processes, such as crystallization, magma degassing, and outgassing, likely exerted a significant role in determining the eruptive style transitions.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Effect of bubbles on the rheology of crystal-rich magma

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Understanding the flow behavior of the multi-phase magma is essential for constraining magma storage and ascent dynamics, eruption styles, and therefore, volcanic hazard assessment. While magma rheology provides a fundamental control on magma flow dynamics, the combined effects of bubbles and crystals with variable shapes on the rheology of three-phase magma have remained poorly constrained. Using dynamically similar analog experiments with glass spheres and high aspect ratio wollastonite particles (as crystal analogs), gas bubbles, and Newtonian silicone oil (as silicate melt analog), we characterize the rheology of three-phase magma under shear deformation. Rheometric data were collected using an MCR 702e MultiDrive rheometer, equipped with parallel plate and concentric cylinder geometries. Preliminary results suggest that a small bubble volume fraction slightly increases the viscosity of the particle-free suspending liquid, whereas it reduces the overall viscosity of a dense particulate suspension. We systematically explore the effects of particle volume fraction, particle shape, and bubble volume fraction on the rheological properties of our analog suspensions. The experimental stress-strain rate data were fitted to the Herschel-Bulkley model to obtain the rheological parameters: yield stress, consistency, and flow index. The implications of our findings for the dynamics of three-phase magma in crustal reservoirs and during effusive-explosive volcanic eruptions are discussed.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Effects of bubbles on crystallization in ascending magma with implications for eruption explosivity

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Magmas erupting during volcanic eruptions often contain bubbles and crystals. Bubbles form as a consequence of supersaturation due to the decrease in the solubility of dissolved volatiles in ascending magma during volcanic eruptions. These bubbles continue to grow due to the decrease in melt pressure and the diffusion of the remaining dissolved volatiles into the bubbles. The microlites, on the other hand, syn-eruptively crystallize due to the degassing of dissolved volatiles, particularly water, in bubbles. The vapor pressure inside bubbles provides a first order control on such crystallization kinetics, and yet, the feedback between degassing, bubble growth and crystallization in ascending magma during volcanic eruptions has remained poorly constrained. Using coupled models of bubble and crystal growth, and magma ascent in a volcanic conduit, this study investigates the effect of bubbles on disequilibrium crystallization in magma. The rates of crystallization from existing studies are included, whereas the rates of magma decompression are varied in the model to map out a wide range of parameter space of degassing and crystallization during explosive styles of eruptions. The effect of bubble growth on crystallization becomes significant under fast decompressing magma during violently explosive eruptions. The implications of the findings of this study on the effusive-explosive transitions in volcanic eruption styles are discussed.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Pre- and syn-eruptive conditions of the 1631 and 1944 eruptions of Vesuvius volcano: implications for eruptive style transition

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Intermediate to evolved alkaline magmas have relatively low viscosities compared to similar calc-alkaline magmas. Despite this, they can give rise to a wide range of eruptive styles, from effusive lava flows to highly explosive, catastrophic eruptions. The processes and the pre- and syn-eruptive conditions driving the transitions between the different eruptive styles remain poorly understood and investigated in alkaline volcanic systems. This study aims to identify the leading causes of these transitions at Mt. Vesuvius, selecting as case studies the 1631 and 1944 eruptions. During the 1631 eruption, the intensity gradually decreased, shifting from a Plinian to Vulcanian phase, whereas the 1944 eruption was characterized by increasing intensity, producing lava flows, followed by vigorous lava fountains and finally a Vulcanian phase. The eruptive style transitions have been investigated through detailed textural, chemical analyses and modelling. The preliminary results indicate that temperature, pressure and crystal content variations could have been parameters controlling the eruptive style during the two eruptions: during the 1631 eruption, the Plinian phase erupted at 900-950 °C, whereas the Vulcanian phases erupted at 1000-1050°C, starting at a pressure of 100 MPa. The Plinian phase shows a lower crystal content than the Vulcanian phase. For the 1944 eruption, pre-eruptive temperatures are relatively consistent from the initial effusive phase to the last Vulcanian phase, ranging from 1030 °C to 1090°C. These products recorded different pressures: up to 300 MPa in melt inclusions hosted in clinopyroxenes, 50 MPa in melt inclusions hosted in leucite. These differences are currently being investigated.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Conduit evolution during explosive activity at an andesitic stratovolcano, an example from Taranaki Mounga, New Zealand

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^^Presenting author * Volcanic conduits play an important role in modulating eruption dynamics by influencing outgassing of ascending magma and the density of eruption plumes. Inhibiting outgassing of magma during ascent promotes explosivity. Increasing the density of plumes through conduit wall erosion increases the likelihood of plume collapse and pyroclastic density current generation. Here, we combine textural and physical property analysis with componentry and field data to provide an overview of conduit establishment, evolution, and closure at Taranaki Mounga, New Zealand. The dominant lithic types across explosive eruptions from both Taranaki's andesitic summit vent and basaltic-andesitic parasitic vent represent material from the shallow conduit and vent. Variable alteration, fracturing and sintering of lithic clasts indicate both juvenile and remnant material comprised a lined shallow conduit system whose permeability and strength evolved across eruptive periods. Componentry analysis and field data from the AD 1655 sub-Plinian Burrell eruption reveals shallow juvenile linings build concentrically inwards and are then removed across different phases of the same eruption. Lining accumulation and destruction in this way correlates with transitions in eruption style. Pumice and lithic textures show the juvenile-lithic transition can occur on intra-eruption timescales, meaning future studies should incorporate characteristics and abundances of the pumice-lithic spectrum to build a full picture of conduit wall evolution both between and during eruptions. This is important for risk assessments based on trends in recent activity as repeated effusive activity may sequentially increase the likelihood for explosivity, and vice versa, at global stratovolcanoes.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

3D visualisation of nanolite aggregation in basaltic magmas using X-ray ptychography: Implications for magma rheology

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Nanoscale crystals, or 'nanolites', are becoming increasingly recognised in natural volcanic clasts and experimental run-products, spanning a wide range of magma compositions and explosivity. Nanolite crystallisation can increase magma viscosity, through the rheological impact of the nanoparticle suspension, by increasing melt polymerisation, inducing chemical and structural changes in the residual melt and facilitating heterogeneous bubble nucleation. Furthermore, due to their large surface area, nanolites may be prone to agglomeration, increasing their impact on magma rheology. However, their morphology, spatial distribution and interaction have yet to be investigated using a three-dimensional (3D) approach. Here we present an innovative 3D reconstruction and visualisation of nanolites in basaltic volcanic scoriae, acquired using X-ray ptychography, an X-ray microscopy technique with nanoscale resolution. Our 3D images illustrate that Ti-magnetite nanolites agglomerate in basaltic magmas. Their agglomeration entraps interstitial melt, increasing their effective volume and their impact on magma viscosity. We support our 3D nanoscale observations with images acquired using SEM and STEM, utilising multi-scale imaging methods to visualise nanolite crystallisation in basaltic magmas. We use our data in viscosity models to evaluate their impact on magma rheology, finding that the rheological changes associated with their

crystallisation may promote magma fragmentation during ascent. Our results not only provide insight into the rheology of nanoparticle suspensions, but also the driving mechanisms of highly explosive, Plinian activity at basaltic volcanic systems.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Comparative petrological study of Pico de Orizaba and Nevado de Toluca stratovolcanoes, Mexico

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Stratovolcanoes show a wide range of eruptive rates and behaviours, potentially reflecting differences in magmatic systems architecture and history, moderated by tectonic factors. However, on a case-by-case basis, the influence of such parameters remains poorly understood. To address this challenge, we conduct a comparative petrological study of two stratovolcanoes showing different eruptive rates and chemistry of erupted products: Pico de Orizaba and Nevado de Toluca, located in the subduction-related Trans-Mexican Volcanic Belt (TMVB). Pico de Orizaba stratovolcano, situated at the eastern margin of the TMVB at a trench-normal distance of about 390 km, has been active since the Pleistocene (650 Ka) and likely last erupted in the 16th century. Over its four main volcanic stages (Torrecillas, Espolón de Oro, so-called Outer Domes and Citlaltépetl), it has erupted a range of basaltic andesite to rhyolite compositions, alternating over time between higher and lower silica content lava. In contrast, Nevado de Toluca, located in the central part of the TMVB at a trench-normal distance of about 300 km, is a long-lived compositionally monotonous stratovolcano, that has predominantly produced dacites and minor andesites since 1.5 Ma, with its last eruption dated at around 3 Ka. We used optical microscopy, Electron Probe Microanalyzer, X-ray Fluorescence and machine learning based thermobarometry and chemometry on newly acquired samples from these two contrasting volcanoes, to trace the parameters influencing their magma generation and the temporal evolution of their volcanic plumbing system architectures.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

A petrological model for use in thermo-chemical-mechanical models of magmatic system dynamics

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Understanding magmatic system dynamics is challenging due to limited direct observations of subsurface processes. Numerical modelling provides a means to interpret indirect petrological and geochemical observations on igneous rocks. Central to magma dynamics is the interplay of complex multiphase fluid mechanics and multicomponent thermochemistry. Models of chemical thermodynamics require costly Gibbs free energy minimisation in systems typically comprising several dozen thermodynamic components. Existing algorithms lack the efficiency and robustness for on-the-fly tracking of petrological evolution in coupled thermos-chemical-mechanical models. Previous coupled modelling approaches have relied on simplified phase relations such as a single phase loop or precomputed lookup tables. Both approaches have strong limitations. Here, I introduce an alternative petrological model that generates multi-dimensional pseudo-phase diagrams over a set of pseudo-components in P-T-X space. This model avoids both expensive energy minimisation as well as oversimplification of phase relations and cumbersome lookup tables but preserves sufficient complexity to capture key trends in petrological evolution such as fractional crystallisation. Model calibration against experimental data and full thermodynamic model results, achieved via standard machine learning techniques, highlights the principal axes of variability, typically revealing 5-6 dominant components correlated to the appearance of a similar number of major phases on the liquidus. Consequently, the model offers significant dimensional reduction compared to full thermodynamic models while preserving critical petrological insights. The calibrated model can then be used to robustly and efficiently track the dynamic evolution of major mineral and melt phases and their major element compositions over large segments of P-T-X space in coupled models.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Numerical modelling of magma ascent dynamics of the 2021 Cumbre Vieja eruption: Insights into conduit processes and eruptive style transitions in mafic systems

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Abrupt transitions in eruptive style are common at low-viscosity mafic volcanoes, presenting significant challenges for volcanic hazard assessment. During the 19th September - 13th December 2021 Cumbre Vieja eruption on La Palma, Canary Islands, exhibited numerous shifts in eruptive styles, making it an ideal case for investigating the physical and chemical processes underlying such transitions. We used a numerical 1D steady-state magma ascent model to study the interplay between conduit processes and eruptive style. The model captures the complex non-linear interdependence amongst key processes: temperature and viscosity evolution, non-ideal gas behaviour, disequilibria in outgassing and crystallization, and volatile exsolution. Input parameters (inlet pressure, magma temperature, volatile and crystal content) are constrained by empirical and analytical data. We investigated several scenarios by varying the input conditions in plausible ranges for this eruption. Simulations show that the system favoured effusive and fountaining behaviour, consistent with the observed dominant styles. However, a change in the degree of coupling between gas and melt may have triggered transitions to explosive style.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Direct observation of vesiculation dynamics in basaltic magmas via in-situ X-ray radiography

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Transitions in eruptive styles at basaltic volcanoes depend on the efficiency of gas-magma decoupling during ascent. Strong gas-melt coupling favours explosive eruptions, while weaker coupling promotes lava flows and fountaining. However, the mechanisms driving transitions between closed- and open-system degassing remain poorly understood due to limited direct observations of bubble dynamics under natural magmatic conditions. Here, we used a novel high-pressure/high-temperature X-ray Transparent Internally Heated Pressure Vessel apparatus combined with X-ray synchrotron radiography to perform in-situ experiments. These experiments enabled real-time, 2D observation and quantification of bubble growth and coalescence in basaltic magmas during decompression from 100 MPa to surface conditions. For low-viscosity magmas, bubbles coalesced and regained a spherical shape within 3 seconds, indicating that gas and melt remained coupled until the final ascent stage (i.e., the last hundred meters of the conduit), consistent with lava fountaining activity. In higher-viscosity magmas, slower bubble recovery facilitated the formation of connected pathways, leading to gas-melt decoupling. This behaviour was directly observed as bubbles expanded, connected to open pathways, and contracted as gas escaped. This study provides quantitative insights into bubble dynamics in basaltic magmas under pre- and syn-eruptive conditions. The novel apparatus advances our ability to observe degassing in real time, opening new frontiers in understanding magmatic processes. These findings are critical for improving our understanding of the mechanisms

driving eruptive styles transitions and enhancing volcanic hazard assessment and risk mitigation strategies.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Magma mixing drastically enhanced by fragmentation and sintering

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Magma mixing results from diffusive exchange following mingling of two magma endmembers. Such exchange requires either long equilibration timescales or small lengthscales. It is often presumed that magmas with starkly contrasting viscosities would not readily mingle via viscous flow; also, the widespread observation of transfer of xenocrysts from one endmember into another endmember (and far from the contact between the two) raises questions as to how crystals transfer across magmas with high viscosities. Such observations are commonplace at Glass Creek dome (Long Valley Caldera, California, USA) which is believed to have formed from the mingling of crystal-poor and crystal-rich rhyolitic endmembers (erupted at Obsidian Dome and Deadman Creek, respectively) during magma transport in the shallow feeder dyke. Here we present a wide range of field observations that suggest that mixing took place in a fragmental state rather than by viscous flow. Thermal analyses of the obsidian indicate multiple glass transition temperatures, commensurate with spatially heterogeneous chemistries, despite common cooling histories over short lengthscales. The observations are congruent with recent models indicating that silicic lavas are the products of agglutination and sintering of pyroclasts in shallow conduits. The diffusion lengthscales, and thus mixing timescales, between mingled pyroclasts would be much shorter than those of larger coherent magma schlieren. We advance that the efficiency of mixing can drastically increased when mingling takes place in a pyroclastic state, which could explain the observation of chemically homogeneous lavas despite the near ubiquity of magma mixing episodes in shallow magmas.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Viscous sintering under load and its implications for the development of permeability anisotropy

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A growing number of field evidence suggests that lavas readily fragment and sinter back together during transport, eruption and or emplacement. In the last decade, advances in the kinetics of viscous sintering have contributed to a better understanding of how fragments may densify into a coherent body under isothermal and non-isothermal conditions, and while the effect of external loading has been theorised, it has not yet been experimentally demonstrated. Here, we use poorly-sintered glass bead cores of 25mm (1:1 aspect ratio). We place the cores in a uniaxial press mounted with a furnace and apply constant loads of 5-100N for 5h at 660°C. We measure porosity pre- and post-experiment in a helium pycnometer. The permeability of each deformed core is also measured in a gas permeameter at confining pressures of 0.7-2.1 MPa in the axial and radial directions to estimate permeability anisotropy. We show that for the samples held below a transitional load of 40N, the permeability in both axial and radial directions is the same and that it is predicted by the existing isostatic permeability models. For samples held at higher loads, we observe higher radial permeabilities than axial, an effect magnified by the load magnitude. Thus, our results corroborate the theoretical framework and have implications for how fluids flow in anisotropically permeable sintered lavas.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Vesicle evolution during rhyolitic Plinian eruptions

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Plinian eruptions of rhyolitic magma are characterized by magma fragmentation, producing pyroclasts with bubble number densities (BNDs) of $10^{15\pm1}$ m^{-3} at discharge rates of 10^6 - 10^9 kg/s. What magma ascent pathways, that is conduit geometries, give rise to Plinian eruptions, and what are the resulting magma decompression rates? Our study addresses this by modeling bubble nucleation and growth under a large number of randomly chosen decompression paths between the chamber and surface, generated using the Monte Carlo method. We use a conduit model to interpret the simulated results, which allows us to derive conduit size and discharge rate and account for permeable outgassing after fragmentation. For each given decompression scenario, the model predicts whether fragmentation occurs and at what depth. Bubble number density, vesicularity, and residual water content of pyroclasts, as well as the magma discharge rate and associated conduit geometry, are all model predictions, as opposed to prior chosen parameters. We find that multiple bubble nucleation events, ranging from three to five, occur during rhyolitic Plinian eruptions, producing a wide range of size distributions. These degassing processes are explained by volcanic conduits, which narrow as they approach the surface. A bubble number density of $10^{15\pm1}$ m^{-3} results from a decompression rate of 1-2 order of magnitude in MPa/s at fragmentation. Additionally, the vesicularity and water content are 0.7-0.9 and 1.0 wt.%, respectively, aligning with observational data.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Porous-permeable evolution of sintering polydisperse, fragmental, hydrous magma

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Understanding the evolution of porosity and permeability is essential to constrain the development of magma buoyancy and so, its eruptibility. At silicic volcanoes, explosive processes may produce deposits of hydrous magma fragments whose porous-permeable networks continue to evolve after deposition; that is, fragments may vesiculate (causing volumetric expansion and dehydration), diffusively outgas (causing contraction and further dehydration) and sinter, (causing sealing of the system). We see that these fragmental systems are often polydisperse, comprising of fragments with a wide range of grain sizes. During our laboratory experiments, we induce temporal changes in porosity and permeability due to sintering of polydisperse fragments which simultaneously vesiculate and diffusively outgas. When a higher fraction of coarse grains are present, greater intra-clast vesicularity is achieved causing a stronger reduction in connected porosity and permeability. Smaller fragments densify faster due to diffusive outgassing, leaving no proof of vesiculation. More polydisperse systems have better packing and the larger contact area accelerates sintering. In our ongoing work, we compare the results to polydisperse sintering at different stages in the field (Mono-Inyo Craters, California). Several outcrops with sintered, highly vesiculated clasts on fracture surfaces are analysed in terms of their grain sizes, water content, inter-clast interactions and the rind thickness. We exploit the variation in clast size and the variable degrees of completion of sintering and diffusive outgassing to unravel the thermal history of the deposits.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Textural and geochemical evidence for melt extraction from a magma mush in Aztec Wash Pluton (Nevada, USA)

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Magmatic textures and compositions illuminate magma dynamics during the emplacement of a large (2 m diameter) felsic enclave (LFE) within granitic mush in Aztec Wash Pluton (15.7 Ma, NV-USA). The LFE is an ellipsoidal microgranite mass inferred to have been nearly solid when it settled at the top of a crystal-rich zone of the magma body. Backscattered Electron (BSE) imaging, Energy Dispersive Spectroscopy (EDS), and X-ray Fluorescence whole-rock data for samples from the granite surrounding the LFE show key textural and compositional differences between granite immediately beneath the LFE and granite located more distant and to the side ("far-field"). Alkali feldspar crystals beneath the enclave have well-defined euhedral rims, while those in the far-field have irregular overgrowths, suggesting continuing growth into larger melt pools. The samples underneath the enclave (69.6-70.0% SiO_2, 1100-1170 ppm Ba, 400-430 ppm Sr) are less felsic than the far-field sample (72.1% SiO_2, 750 ppm Ba, 330 ppm Sr), also suggesting less retained melt. We conclude that impingement of the LFE led to enhanced melt extraction. The composition of the far-field sample is typical of Aztec Wash pluton samples interpreted to represent cumulate mush (70.0-72.4% SiO_2, 640-1100 ppm Ba, 250-440 ppm Sr; Harper et al. 2004 and our new data). For comparison, "non-cumulate" Aztec Wash samples that may represent input magma are distinctly more felsic (72.3-73.9% SiO_2, 570-690 ppm Ba, 170-270 ppm Sr). Our beneath-LFE compositions indicate the greatest melt depletion identified among Aztec Wash granites, substantially more than in the typical cumulates.

Theme: 3. Volcanic processes

Session 3.2: Exploring the physical and chemical evolution of magmas in volcanic plumbing systems: implications for magma reservoir, conduit processes and eruptive styles

Allocated presentation: Poster

Magma fragmentation in scoria cones, a comparative study of Cinder Cone (California, USA), Sunset Crater (Arizona, USA) and Paricutin (Michoacan, Mexico)

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We present a comparative study between three scoria cone tephra sheets: Cinder Cone, Sunset Crater and Paricutin. Cinder Cone evolved from Hawaiian/Strombolian to violent Strombolian style, creating two main tephra units. Sunset Crater ranged from Hawaiian and Strombolian to subplinian, generating five main tephra units. Paricutin was composed of three different phases with the eruptive style reaching violent strombolian. We complete our dataset with Etna paroxysm episodes of lava fountaining from February-March 2021. We use the same methodology for all of our samples : we focus on three specific size fractions [coarse lapilli from 5.7 to 4 mm (− 2.5 to − 2ϕ), coarse ash from 0.71 to 0.5 mm (+ 0.5 to + 1ϕ), and very fine ash from 88 to 63 μm (+ 3.5 to + 4ϕ)] to compare componentry, morphometric parameters of individual juvenile fragments, and internal textures (crystallinity, vesicularity), based on microscope and SEM imaging. Our goal is to link measurable parameters of the particles to fragmentation processes and eruptive styles of the volcanoes. Our results show an importance of componentry for morphometric parameters and internal textures, sometimes more than between different tephra units during an eruption. The presence of different types of juvenile clasts in variable proportions could be a consequence of conduit zonation. Therefore, even if the eruptive style is responsible for the type of tephra deposits, the different types of juvenile components produced by local variations of magma (vesicularity, crystallinity) play a role in magmatic fragmentation.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Talk [Invited]

A Candidate Glaciovolcanic Plateau near Pavonis Mons, Mars

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Lava and ice are thought to have interacted in several regions of Mars, including the flanks of the Tharsis Montes, the Sisyphi Montes near the south pole, and Northeast Syrtis Major. Due to the limited resolution of orbital data and the unconsolidated material that covers many of these regions, candidate glaciovolcanoes on Mars are typically identified based on morphometry and context alone. The glacial fan-shaped deposit (FSD) northwest of the Pavonis Mons volcano contains several landforms that are well-exposed and which have been repeatedly imaged by the Mars Reconnaissance Orbiter's HiRISE camera at ~26 to 52 cm/px resolution. Having recently published an analysis of a steep-sided ridge in the northeastern part of the FSD, which we interpreted as a hyalotuff-dominated glaciovolcanic ridge, we now present a description and interpretation of a steep-sided plateau in the center of the deposit, which we term the "Central Plateau". The Central Plateau is ~30 km long by ~15 km wide and ~350 m high, with several ridges and mounds hundreds of meters high superimposed atop it. Outcrops mostly appear subhorizontally layered, with some appearing bouldery or vertically striated. Evidence for collapse of the sides is frequent and includes boulders tens of meters wide at the foot of the plateau and edge-parallel fractures along its upper surface. Its large-scale morphology is similar to an enigmatic subset of buried mounds at nearby Arsia Mons; our ongoing study of the better-exposed Central Plateau may provide insight into the buried mounds' formation processes.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Talk [Invited]

The role of groundwater in explosive eruptions: Insights from experiments and modeling

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Little is known about the quantitative parameters necessary to generate explosive interactions between magma and wet sediment. This study combines melt experiments, numerical modeling, and laboratory measurements to constrain these parameters. We conducted 13 remelted basaltic melt pours at SUNY Buffalo of 22-50 kg of melt into cone-shaped sediment piles with summit basins. We varied the host sediment grain size from sand to gravel and water content from dry (0-7% water) to saturated (>34-40% water). Each experiment had thermocouples below the summit basin in the sediment, several moisture sensors, multiple video, still, and infrared cameras, and a surrounding tarp for ejecta collection (for wet experiments). Each pour resulted in a summit basin lava pool, and temporary and permanent changes in the sediment contact zone. Of the 13 experiments, five produced ejecta. Of these, three had water tables maintained by surrounding impermeable barriers, and the other two had frozen saturated sediment. Despite the melt rock being essentially degassed due to several hours of melting, explosive behavior was still generated. Explosive behavior required several conditions: sufficient heat pulse from the melt volume, sufficient initial water supply, additional water able to flow through the sediment, and limited ability to vent generated steam except through the melt. Numerical modeling of the experiments (COMSOL multiphysics) shows that the relative supply and mobility of the water and steam within the sediment is key. Under the subset of conditions where steam can be forced into the melt, even a degassed melt can generate explosive behavior and ejecta.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Talk

Volcano-permafrost interaction in Iceland and associated hazards

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Active volcanoes are the most dynamic landforms that evolve through the construction and destruction of their edifices, which can strongly affect the environment. Degrading permafrost can also be dynamic and lead to mass-wasting. Volcanoes and permafrost have been studied using different approaches. However, volcano-permafrost interaction hasn't received the deserved attention and remains poorly understood, though it can lead to hazardous events associated with flank instability, explosive activity, and collapsing ground. Discontinuous permafrost can be found in Iceland above 800 m a.s.l, and sporadic permafrost can be observed at lower elevations. Permafrost at active volcanoes can be presented in three main forms – frozen ground, buried ice, and rock glaciers. Here, we present our results from the two study sites – Askja and Hekla volcanoes – where permafrost features can be observed in abundance. Analyzing multitemporal (1945-2024) and multisensor (visible, infrared, and SAR UAV) data, we address the question of permafrost variations under the influence of volcanic activity and the potential effects on the environment. We suggest that volcano-permafrost interaction at Askja can induce slope instability and lead to hazardous landslides, as happened in 2014, while at Hekla, the main hazard comes from lahars that can emerge from rapid rock glacier melt in the course of an eruption; such situation occurred in 1947. Besides, both sites are subject to intense thermokarst processes due to the thawing of ice layers buried by volcanic deposits. Our results from the two case studies can facilitate a general understanding of the volcano-permafrost interaction and associated hazards.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Talk

Effect of melt-domain size on vapor film stability with implications for explosive submarine eruptions

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The explosivity of volcanic eruptions involving external water is primarily governed by factors like the duration of water boiling regimes and associated magma-to-water heat transfer rates. Melt fragments ranging from micron to cm-size are observed during such interactions, therefore fragment size likely provides a first order control on the efficiency of magma-water interactions. However, the impact of fragment/domain size on water boiling regimes and their timescales has remained poorly understood. This study investigates the effect of melt fragment size on water boiling dynamics using high-temperature experiments with millimeter-sized spherical, re-melted mafic rock samples (~1388 K initial sample temperature). The samples were submerged in water at temperatures ranging from ~276 to 365 K. High-speed video analysis captured the boiling regimes, allowing for the determination of vapor film timescales and comparison to existing results on centimeter-sized domains. Our experimental results reveal that mm-scale fragments cause a significantly shorter vapor film lifetime than cm-scale fragments, where this difference increases with increasing water temperature. Using the experimental data and heat transfer model, the Leidenfrost temperatures, i.e., the temperature where vapor films collapse, were estimated. Our findings provide new constraints on the time available for melt - water mixing and the potential for any necessary external triggers to initiate explosive interactions. Thus, the outcomes of this study have implications for better understanding the energetic magma-water interactions, potentially leading to explosive submarine volcanic eruptions.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Talk

Trajectories of large particles in supersonic jets: Implications for volcanic ballistic projectiles

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Explosive volcanic eruptions are known to produce supersonic jets, which play an important role in quantifying volcanic processes and their hazards. One such hazard is the explosive ejection of rocks that describe ballistic trajectories, so-called volcanic ballistic projectiles (VBPs). Their initial acceleration by the jet is an active area of research, however, further insights are still needed to fully understand the process. To study the effect of the supersonic jet, open-ended shock tube experiments with spherical glass beads as VBP surrogates were conducted, and bead trajectory data and schlieren/shadowgraph images of the jet obtained. Numerical simulations using OpenFOAM were conducted to obtain quantifiable flow field data by reproducing the steady-state jet structure from the images. Trajectory calculations with the flow field data obtained from OpenFOAM simulations successfully reproduced the measured vertical velocity profiles of the beads. This trajectory calculation method was applied to ballistic data from the 1997 Vulcanian eruption of Soufrière Hills and the observed maximum impact distances were successfully reproduced. The analysis of the calculated trajectories at Soufrière Hills revealed that VBPs are accelerated by the supersonic jet until they cross the Mach disk. VBPs cross the Mach disk after the jet reaches its steady-state and before the steady-state ends, with the Mach disk and shock structure collapsing towards the vent. This implies that VBPs are predominantly accelerated by the steady-state flow field of the supersonic jet.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Talk

Cracking the code: Empirical analysis of damage fracture occurrence, abundance and morphological complexity for natural and experimental volcanic ash particles.

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Fractography, the study of fractures in materials, components, and structures, is essential for understanding material failure mechanisms. Two key principles in fractography are: (1) greater energy exerted results in more fractures, and (2) higher energy release rates lead to increased fracture complexity. Using these principles, we conducted an empirical analysis of basaltic to rhyolitic ash particles from eruptions and analogue experiments to examine damage fracture types and abundances produced by different fragmentation processes. Fracture types and abundances were documented with high-resolution backscattered electron images of 4 phi (~63 um) ash fragments captured with a Zeiss FEG-SEM. Experimental particles representing thermal granulation, fuel-coolant-interaction (FCI) processes, abrasion, and shattered Prince Rupert Drops were compared with natural samples from eruptions including Surtsey, Havre, Katmai, Hunga, and Sakurajima. We introduce a Damage Fracture Intensity (DFI) index that accounts for fracture prevalence, relief, complexity, and interactions with glass-crystal boundaries. DFI values enable inference of relative energy densities and release rates associated with fragmentation processes recorded by the particles. Our results reveal narrower DFI variations in experimental samples compared to natural ones, reflecting the broader range of processes active in eruptions versus targeted mechanisms in experiments. Both natural and experimentally created samples, regardless of composition, when influenced by magma-water interactions showed a higher proportion of particles with extensive and complex damage fractures. These findings demonstrate the utility of DFI in linking particle damage to fragmentation energies and mechanisms, enhancing our understanding of eruptive and experimental fragmentation processes.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Talk

Investigating the Seasonal Snow and Hydrological Ground Deformation Signals at Katla Volcano, Iceland

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Mass unloading at volcanic edifices has the potential to influence the stability of magma bodies—either bringing them closer or further from failure. Katla volcano in Iceland underlies Mýrdalsjökull, the fourth largest glacier in Iceland, but undergoes the largest seasonal deformation of all Icelandic volcanoes; up to 4 cm and 5 cm horizontally and vertically, respectively, at AUST GNSS station. The last confirmed eruption of Katla occurred in 1918, but there has been elevated seismicity and jökulhlaups recorded at the volcano in 1955, 1999, 2011, and 2024. A series of jökulhlaups have occurred at Katla since July 2024 which have caused up to 7 cm of horizontal deformation at AUST during one jökulhlaup. In this work, an elastic, 3D Finite Element (FE) model, using COMSOL Multiphysics, including realistic topography and ice unloading based on recent data from Mýrdalsjökull, was created to investigate the effects of seasonal load variations on the observed deformation signal and changes in failure threshold and failure location at a magma body. Seasonality in the hydrologic system is also modeled to see if it recreates the observed deformation during jökulhlaups at Katla. The predicted deformation from the FE model is compared to the observed GNSS time series from Katla to discern if seasonal snow loading and/or pressure modulation in a magma body can explain the deformation. 3D flat, homogenous, elastic FE models of a simple seasonal snow load can explain part of the observed deformation signal in both the horizontal and vertical components.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Talk

Hydrological Shifts in High-Altitude Volcanic Systems: Implications of permafrost thaw at Ojos-del-Salado (27°S)

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Ojos-del-Salado, the world's highest volcano, presents a unique setting where post-volcanic heat and cryospheric processes converge, influencing surface and subsurface hydrology. Nevertheless, as permafrost thaws (as in Deception Island or the Klyuchevskaya volcano group, Kamchatka, Russia), there could be potential shifts toward deeper hydrological pathways, raising questions over hydrothermal mixing. This transition might not only occur in other volcanic regions but have given rise to the current groundwater background field from colder from paleoenvironments. Considering geothermal dynamics within post-volcanic landscapes, where asymmetrical energy outputs (e.g. localized high-enthalpy hydrothermal ponds), our aim is analyzing how (i) permafrost aggradation outlived geothermal subsurface dynamics, and (ii) how it might evolve into non-linear groundwater pathways thereon, and elsewhere. Our studies with the PermaChile network cover 12-year surface temperature records, and geophysical sub-soil characterizations to assess permafrost stability and distribution. Additionally, hydrogeological simulations assessed scenarios under downward and upward warming. Our findings evidenced sporadic permafrost at 5,200m ASL and a non-sporadic, 20-30 m-thick layer at 5,800m ASL. Unlike settings with persistent geothermal anomalies that might continuously thaw permafrost from below, the configuration appears to result from a heterogeneous energy budget, influencing thermal dynamics within the upper 10 meters of the massif above 5,000 m ASL. These findings contrast with conditions observed at Chajnantor volcano (23°S), where geothermal input restricts permafrost thickness, promoting higher confined aquifer transmissivity, and highlighting the significant hydrological impact of geothermal variability across high-altitude volcanic systems.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

A timeline of post-eruption glacier development and glacier recovery in times of global warming – an example from Eyjafjallajökull volcano, Iceland and its 2010 eruption

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Although research on glaciovolcanism has increased significantly in recent years, studies usually focus on eruption processes and their direct hazard implications, while long-term effects, e.g., on the overlying glacier cover, receive little attention. For example, numerous studies exist on the 2010 Eyjafjallajökull eruption itself, but few follow-up studies have been published on how the glacier cover has evolved and how the vent areas have changed since the eruption. During the eruption, three different areas of the Eyjafjallajökull ice cap were affected: (i) the summit caldera with the volcanic vents active for six weeks; (ii) the short-lived eruption fissure on the south flank; and (iii) the Gígjökull outlet glacier north of the caldera, which was affected by a subglacial lava flow. We provide a comprehensive overview of how these areas have changed with time and illustrate differences in their recovery. While signs of the eruption on the southern flank have completely vanished, the glacier within the caldera has not fully recovered. Observations from October 2024 also indicate the formation of a new minor cauldron near the northern rim. Gígjökull continued to retreat until 2015, but then started to readvance and has recovered ~1 km of length through 2024, although overall the Eyjafjallajökull glacier is retreating. Our results are primarily based on aerial photographs from overflights, visits of the investigation area, and different types of remote sensing data. Our studies are critical for understanding how single events can impact long-term glacier development and their recovery in times of global warming.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Noble gas isotopes at Deception Island (Antarctica) reveal degassing-derived eruptions and cosmogenic helium signatures: implications for the current high levels of volcanic activity and geochronology of its eruptive history

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Deception Island is one of the most active volcanoes in Antarctica with more than twenty explosive eruptions in the past two centuries. Any future volcanic eruption(s) is a serious concern for scientists, tourists, marine ecosystems and even for global oceanographic processes. Currently, it is highly challenging to carry-out -at least- low frequency volcanic gas monitoring at Deception Island because of the arduous climatic conditions and its remote location. We managed to do it for connecting the information of He, Ne, and Ar isotopes measured in olivine samples of the main past eruptive events with their on-going bubbling emissions at surface. Results reveal (i) ascending primitive magmas outgassed volatiles with a MORB-like He isotopic signature as at present day data; (ii) intensive degassing (fractionated $^{4}He/^{40}Ar^{*}$), before the beginning of the main eruptive episodes, as nowadays. All this demonstrates how the pre-eruptive noble gas signals of volcanic activity is an important step toward a better understanding of the magmatic dynamics and has the potential to improve eruption forecasting. We also describe the cosmogenic signal (i.e. high $^{3}He/^{4}He$ ratios of 56-910 R_A) in the crystal lattice of olivine phenocrysts (total fusion in crushed poweder) much higher than the magmatic values previously obtained in the inclusions of the same olivines. The cosmogenic details reveal age ranges of c. 4-6 Ma

and c. 4 ka for the pre-caldera and syn-caldera deposits, respectively, thus being the first quantitative geochronological approach to date the formation of Deception Island.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Hydrogen (δD), oxygen (δ18O) and noble gas characterization of volcanics in the Hofsjökull volcanic area (Iceland): implications for magmatic degassing in sub- vs. post-glacial eruptions

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Geochemistry of volatiles in active volcanoes provides insights into the magmatic processes at depth, such as magma evolution and degassing, which can be implemented into volcanic hazards assessment. Polar magmatic systems in Iceland represent excellent natural laboratories with numerous historical and current volcanic activity. Hydrogen, oxygen and noble gas isotopic variations in volatiles trapped in igneous rocks (subglacial glass and/or mafic crystals) of the Hofsjökull volcano provide essential information on past mechanisms controlling the eruptive history (sub- and/or post-glacial) of this large volcano with potential implications for other glacial volcanoes worldwide. Hydrogen and oxygen isotope ratios reveal (i) plausible "ice-age" water contribution in the sub-glacial samples, and (ii) shifting degassing conditions from closed sub-glacial stage to open degassing system in the interglacial stages, which might be due to the decreasing glacier load. Helium isotope data reveal higher affinity to a plume origin than a MORB for its magma source ($^{3}He/^{4}He$ up to 23.8 R_a), whereas the ^{4}He-^{40}Ar^*^ abundance systematics of the sub-glacial glasses are inconsistent with extensive degassing possibly due to the glacial loading above the volcanic plumbing system. Integrated petrologic features infer fast magma cooling in both sub- and post-glacial samples and different chamber(s) depths.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Size and Salt Matter: Key Ionic Controls on S-Scavenging by Water Droplets

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Hunga Tonga-Hunga Ha'apai 2022 (HTHH) is arguably the largest explosive eruption in the satellite era and it is marked by a near absence of climate effects from sulfate aerosols. Space-borne and in-situ cloud measurements and chemical analyses of fresh proximal tephra deposits support sulfur scavenging by volcanic particles as a major process influencing the longevity of HTHH sulfate aerosols. A key underlying control may be the extent of seawater entrainment during magma-water interactions to deposit sea salts on ash surfaces and change the ash hygroscopicity. We hypothesize that the growth of many heavy cloud droplets on sea-salt-coated ash particles led to a rapid removal of volcanic SO_2 during HTHH by droplet scavenging and aqueous reaction with dissolved seawater Ca^{2+}. From preliminary calculations we identify a positive feedback between aqueous sulfate production and cloud droplet growth. $CaSO_4$ production in droplets depletes dissolved SO_2, encouraging further uptake of $SO_2^{(g)}$. Sulfur uptake into seawater droplets can be diffusion- or kinetic-limited depending on the ratio between the particle Reynolds number and the Damköhler number. In contrast, the absorption of sulfur into entrained droplets produced during eruptions through freshwater is limited by the solubility. Initial results suggest that these differences can explain the wide variability of stratospheric sulfur injection efficiency observed for eruptions through freshwater and seawater. We provide a lookup table of scavenging efficiency for atmospheric climate models, and suggest considering source water salinity when predicting volcanic effects on climate.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Unravelling Transient Phreatomagmatism in the 1982-83 Galunggung Eruption through Grain Size and Textural Analysis of Pyroclasts

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The 1982-83 Galunggung eruption was a complex eruption involving both magmatic and hydromagmatic phases. The eruption began with the destruction of the 1918 dome (P1a) involving fresh basaltic magma (P1b), followed by a paroxysmal phreatomagmatic phase (P2) with the same magma composition, and ended after a strombolian phase involving more primitive magma (P3). In this study, we characterise the pyroclasts of the different eruption phases based on their grain size distribution, components, morphometry, and textures. Based on the stratigraphic profile, pyroclastic layers show a compositional change from matrix-rich density currents in P1 to clast-rich fall-dominated deposits in P2 and P3. The abundance of lithics and accreted ash-rich layers in the P2 strata indicates conduit erosion, water interaction, and more effective fragmentation during this transient phase. Subangular to subrounded ash particle shapes in P2 illustrate brittle and ductile fragmentation, possibly with variable excess water ratios relative to the basaltic magma. Vesicularity in P2 is lower (ca. 26%) than in both P1 and P3 (ca. 50%). Phenocryst crystallinity in P2 is higher than in the other phases, around 57%. P2 magma is therefore thought to represent the deeper levels of the magma reservoir feeding P1b. With >10% MgO, P3 indicates a new supply of primitive magma. Microlite number densities in both P2 and P3 range from $10^{6.6}$ to $10^{7.2}$ mm^{-3}, consistent with decompression rates expected for strombolian-style eruption mechanisms.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Decoding Water-Magma Dynamics through Ash Analysis at Torfajökull

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Torfajökull, located in Iceland, is known for its complex volcanic activity, including both explosive and effusive eruptions. This study examines ash particles smaller than 4 phi from the Torfajökull volcanic system to determine the presence and extent of water-magma interactions. Understanding water-magma interactions is crucial for interpreting past volcanic events and assessing future hazards. Ash samples were collected from the 870 CE eruption deposits around Torfajökull. Particles were mounted on carbon tape and imaged with the Backscattered Electron Detector of a Zeiss FEG-SEM, in order to image particle shapes and surface textures. With MatLab tools PARTIcle Shape ANalyzer (PARTISAN) and DendroScan we analysed particle shape morphology. Specific attention was given to identifying characteristics indicative of phreatomagmatic activity, such as quenching cracks, vesicle shapes, and damage fracture abundance, type and complexity. Preliminary results indicate that a significant portion of the ash particles exhibit textures consistent with rapid cooling and fragmentation in the presence of water. These findings support the hypothesis that water-magma interactions played a substantial role in the formation of these deposits from Torfajökull. Further quantitative analysis and comparison with experimental data will refine our understanding of the processes involved. This research contributes to volcanology by providing insights into the mechanisms of explosive eruptions and the role of external water sources. The outcomes have implications for volcanic hazard assessment and risk mitigation in regions with similar volcanic systems.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

The role of hydroclimate on magma-water interactions at hydraulically-charged ocean island volcanoes

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The interaction of ascending magma with groundwater or surface water may produce phreatomagmatic explosions that, due to their violence and unpredictability, may increase the hazard potential of an eruption. To investigate the link between groundwater variations and phreatomagmatism, we analysed the volcanic record of Flores Island (Azores), which includes several monogenetic magmatic and phreatomagmatic eruptions in the last 300 kyrs, together with local and regional climate reconstructions. Our results show that in the long term (>10 kyrs), magmatic eruptions dominated during dry/colder periods, while phreatomagmatic volcanism occurred predominantly in wet/warmer periods. In the short term (<10 kyrs), magma-water interactions were controlled by variations in eruption rates, which allowed water to access the active conduits/craters. Accordingly, rainfall variability had a secondary role given that groundwater remains ubiquitously available in this setting, even in periods with lower precipitation. Here, we confirm that on island volcanoes under heavy rainfall conditions and with permanently charged shallow groundwater bodies, variations in magma output rates of monogenetic eruptions, rather than short-term hydroclimate variations, trigger phreatomagmatism and consequently increase volcanic hazard.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Volcanic controls on glacier elevation

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Glaciated volcanoes pose heightened risk to societies compared to their ice-free counterparts. Monitoring of glaciovolcanic processes is therefore of vital importance, as it could reveal fundamental changes in volcanic activities. This is especially relevant because traditional surveys of volcanic activity may be hindered by glacier cover and/or remoteness. Volcanic activity has the potential of asserting controls on the dynamics and mass balance of nearby glaciers. Previous studies have shown that some volcanoes negatively affect the mass balance of overlying glaciers. Here we present the first global analysis of volcanic effects on glacier mass balance by investigating glacier elevation distribution. We demonstrate that, globally, volcanoes modulate the elevation of overlying glaciers, irrespective of local topography and climate. We further present results from multitemporal automated tracking of glacier mass balance and dynamics around volcanoes.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Modeling the Effects of Ice and Volcanic Cone Loading on Dike Propagation in Arc Settings: Implications for Mocho-Choshuenco Volcano, Chile

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The response of magmatic systems to ice loading in continental arc settings is shaped by shallow crustal stress changes, which are influenced by volcanic topography and ice distribution. We develop a model that integrates crustal stress calculations under glaciated stratovolcanoes with a model for dike propagation that accounts for stresses induced by both volcano and ice loads. Our model incorporates spatial variations in ice thickness influenced by volcanic topography. Applying this framework to the southern Andean Volcanic Zone, where stratovolcanoes were capped by the ~2-km-thick Patagonian Ice Sheet (PIS) during the Last Glacial Maximum (LGM), we find that the weight of the volcanic edifice is a greater barrier to dike ascent than the ice sheet itself. However, ice loads introduce a "pinching point" of concentrated compressive stress beneath a volcano, where dikes ascending from below are more likely to stall, while those initiated above this point are squeezed upward. Model results suggest that ice loading could paradoxically facilitate shallow dike ascent while hindering deeper magma transport, a hypothesis we explore using new thermobarometry data from Mocho-Choshuenco Volcano, Chile. These data reveal a deepening of mafic magma source depths by ~3 km during the LGM, accompanied by increased magma differentiation to form silicic reservoirs that erupted after the ice disappeared. These changes could be explained by dikes stalling at greater depths during the peak of the PIS, cutting off recharge to shallower magma reservoirs while promoting recharge at deeper levels, providing a mechanistic basis for observed links between glaciation and volcanism.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Influence of the bedrock on maar fragmentation processes

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Maars, that are the second most abundant terrestrial volcanic edifices, result from magma water interaction, also called MFCI (Molten Fuel-Coolant Interaction). As a result of this type of interaction, the intensity of the explosions is high despite the small volumes emitted. Furthermore, these explosions occurred in depth, excavating the substrate to form a diatreme. Consequently, the substrate is involved during the fragmentation process. In order to study the impact of the bedrock on maar fragmentation processes we focused on two maars whose emplaced into two distinct substrates. The first is the maar de Jaude (French Massif Central, France), located in soft sediments. The second, is the maar de Kawéni (Mayotte, France), situated in a hard volcanic bedrock. In addition, these two volcanic edifices are part of a quiescent volcanic province for the former and an active one for the latter. Field studies allowed us to reconstruct the eruptive scenario of each maar and identify interactions between the substrate and the magma. In the case of the edifice emplaced in a soft substrate, the interaction occurred between the magma and wet sediments. The explosivity in this type of mingling is damped compared to pure water-magma interaction. Besides, textural analyses of the vesicles and crystals permitted to characterize the pre-eruptive conditions of the magma. Indeed, the explosivity of phreatomagmatism is controlled by the water/magma mass or flux ratio. Thus, textural analyses bring constraints on the magma flux which should modulate the influence of the substrate on the fragmentation process.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Damage Fractures as evidence of Fuel-Coolant-Interaction amplified fragmentation. Insights and comparisons from the 2022 Hunga and 1883 Krakatau eruptions.

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The explosive eruption of Tonga's Hunga Volcano on 15 January 2022 produced a >40 km plume, damaging tsunamis in Tonga, a global meteotsunami, sea-surface pyroclastic density currents, and eruption-fed submarine density currents. We analysed damage fractures on 4 phi (63-88 micron) ash particles from both submarine and subaerial deposits of the 2022 Hunga eruption and compared them with samples from the climatic phase of the 1883 Krakatau eruption. Particles were mounted on carbon tape and high resolution, high magnification images were captured using the Backscattered Electron Detector of a Zeiss FEG-SEM. Damage fracture analysis provides insight into energy expenditure during fragmentation. Greater energy expenditure increases fracture abundance, while increased density of energy expended creates more-complex damage fractures. Using a Damage Fracture Intensity (DFI) index—accounting for fracture prevalence, relief, complexity, and interactions with glass-crystal boundaries—we find up to 83% of particles from Hunga samples exhibit severe to extreme damage. This significantly exceeds the 19–34% observed for the climatic phase of Krakatau, and lower fractions yet for many other eruptions. Damage fracture intensities as high as Hunga's have only been documented for particles created by fuel-coolant-interaction (FCI) experiments. The very high abundance and complexity of fractures on Hunga particles indicate that very high densities of energy were expended during fragmentation. We infer from this that intense magma-water interaction of fuel-coolant type produced these fractures, which provide a physical record of the extreme fragmentation processes that characterised one of the most powerful explosive eruptions ever recorded.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Using analytical constraints and numerical models to understand eruption dynamics of prehistoric submarine explosive eruptions: Case study of Myojin Knoll caldera eruption, Izu-Bonin Arc Japan

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While it is broadly known that vent depth below sea level is a critical factor in modulating explosive versus effusive eruptions, the exact depths for a range of eruptive parameters are only now being established. This information is important for hazard assessment of submarine volcanic centers near populations, such as those in the SW Pacific nations. We conducted detailed analytical work with numerical modeling to examine the plausible eruption depths and dynamics for the prehistoric syn-caldera eruption of Myojin Knoll volcano in the Izu-Bonin arc, Japan. Myojin Knoll has a deep (1400 mbsl circular 7x6 km caldera with scalloped steep walls ranging from 500 m to 900 m. The intra-caldera geology and volcaniclastic stratigraphy were observed, described, and sampled during 13 dives of JAMSTEC submersible Shinkai. The syn-caldera pumice is the uppermost stratigraphic unit of Fiske et al. (2001) and is 150-200 m thick, containing white plagioclase quartz phyric rhyolite (73-75 wt.%). This deposit is correlated with a thick blanket of pumice extending from the volcanic edifice. Microtextural observations, geochemistry, melt inclusion and glass volatile analysis were conducted to provide constraints on the magma and its ascent history for numerical modeling. Preliminary modeling suggests that the syn-caldera magma ascent rates were in excess of 10^8 kg/s, and that fragmentation depths were likely shallower than the shallowest part of the present-day caldera wall. One aim of our study is that this workflow can be used for other submarine volcanoes with well-constrained observations and samples to understand the eruption history and risk.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

The role of magma diversion, withdrawal and groundwater in the excavation of craters and diatremes cut into the substrate

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University of Otago Dunedin, NZ Earth's hydrosphere envelopes the globe, so why aren't all volcanic eruptions phreatomagmatic? Why do diatremes – large and deep volcanic "vent" structures created by phreatomagmatic activity – form by small-volume eruptions rather than large ones? The answers are because bringing magma into contact with water is necessary, but not sufficient, for producing magma-water explosions, and effective excavation relies not on sustained jets, but explosions. Explosions originate from destruction of in-ground seals by accumulation of compressed vapor in e.g. hydrothermal explosions, or from phreatomagmatic explosions taking place below ground level. Magma rising in a dike can cause phreatomagmatic explosions, but the general process of advancing a crack driven by molten rock inhibits explosive contact. Dike magma is confined by crack walls, and its heat and the pressure it exerts both act to drive water away from the dike. To support explosive interaction, magma must somehow capture volumes of water, or "self-drive" interaction by inducing water to enter gaps formed by magmatic fragmentation. Magma driving a dike upward can cease to rise, for example when lateral propagation drains the magma outward. In this situation, the magma surface retreats locally down the dike, leaving unsupported fissure walls above. Failure of these walls can allow entry of the ubiquitous groundwater, while dropping impactors onto the magma surface. Strombolian-style fragmentation can also take place in the fissure as gas bubbles rise through the stagnant or retreating magma. These are ideal conditions for triggering of magma-water explosions, underground, without large volumes or high fluxes of magma.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

The Comparison of Xenoliths in Eruptive Deposits at Dotsero and Cerro Overo Maars

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Phreatomagmatic eruptions occur when magma explosively interacts with subsurface water, forming craters and displacing crustal rocks, some of which become xenoliths. This project investigates the relationship between eruptive styles and xenolith characteristics at two phreatomagmatic volcanoes: Dotsero Maar in Colorado, USA and Cerro Overo Maar in Chile. Dotsero Maar is characterized by three main pyroclastic deposits: welded spatter, red vesicular tuff breccia, and lithic-rich lapilli tuff. All deposits include quartz, sandstone, and siltstone xenoliths with evaporites in the later two deposit types. In contrast, Cerro Overo Maar features ignimbritic, dioritic, and granitic xenoliths, along with olivine crystals and fine scoria. To examine the thermal and eruptive history of Dotsero Maar, xenoliths ejected during different eruptive phases were analyzed, focusing on quartz- and evaporite-dominated xenoliths. Scanning Electron Microscopy was used to study the boundaries between sedimentary xenoliths and the igneous host, while X-Ray Diffraction was used to obtain mineralogical information about the quartz xenoliths and determine the quartz phase for comparison against the regional host rocks. Petrographic analysis was used to obtain textural evidence of magma-sediment mixing and signs of melting or chemical alteration of xenolithic material. The occurrence of evaporite xenoliths and quartz in Dotsero Maar's deposits provides insights into the thermal history of the eruption. These findings are compared to Cerro Overo Maar, where the composition of crustal rocks is less constrained, contributing to the understanding of phreatomagmatic eruptions and eruption dynamics.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

The Chronology of the 15 January 2022 Hunga Eruption revealed through eye-witness descriptions, tephra and tsunami deposition

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We present an overview of the chronology of the explosive 15 January 2022 Hunga eruption. This 11-hour event is described in ten distinct stages. *Pre-climax* pumice rafts, arriving to the shore of Tongatapu in early January, are associated with Surtseyan eruptions from 29/12/21–04/01/22 (*stage-1*). Pumice rafts arriving post-eruption are produced during the onset of the climatic phase of January 15th, occurring shortly before 04:00 UTC (*stage-2*). Afterwards, two waves were witnessed at Tongatapu. Firstly a ~15–20 min period of lapilli fall (~04:40–05:00 UTC, *stage-3*) was recorded in phone videos on Tongatapu and Eua (65–115 km from the volcano). The 0.5–5 cm diameter, low-density particles formed a clean, sparse layer (approx. 1–2 particles/10 cm^2). Next, coarse-medium ash fell (*stage-4*), as the island went into darkness. On the western Tongatapu coast, *stage-4* fall is covered by a tsunami deposit (05:05~15) and *stage-5* fall lies below the largest tsunami deposit of ~05:45 UTC. *Stages-6, 7, and 8* are represented by layers (~1 cm each) of medium-sized ash particles above the largest tsunami. A final thin layer of ash fall (*stage-9*) is above a tsunami deposit of ~08:45–09:00 UTC. The waning activity (*stage-10*) is represented by surtseyan fresh bombs. Tephra deposits are pumice-dominated initially, and become generally finer, denser and less sorted over time. The dispersion axis of the fall was weakly directed towards the ESE. Particle physical characteristics suggest that apart from the initial minutes, the primary fragmentation mechanism was magma-water interaction.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Volcano-glacier interactions during a silicic phreatoplinian eruption at Katla volcano in the Younger Dryas

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Silicic eruptions that occurred at the end of the last glaciation at Katla volcano have distributed tephra across northern Europe and the North Atlantic. The resulting tephra layers are valuable stratigraphic markers for Quaternary studies, but since the eruptions have likely all occurred through an ice cap, proximal deposits are sparsely preserved. We present detailed geological maps for two nunataks exposed in the Mýrdalsjökull glacier. The nunataks record explosive eruption of silicic tephra with synchronously emplaced rhyolite lava flows and intrusions. Based on physical characteristics of the deposits, we infer a phreatoplinian eruption involving explosions and lava effusion from multiple englacial vents around the Katla caldera. $^{40}Ar/^{39}Ar$ dating of the capping lavas determined ages of ~12 ka for both nunataks. These ages, as well as the geochemistry, of the lavas and tephras are comparable with those of the Vedde Ash, a well-known distal ash layer originating from a Katla eruption dated to 12.1 ka. We propose that the nunataks preserve the proximal deposits of this significant eruption. At the end of the last glacial period, retreat of the Icelandic Ice Sheet was rapid and coincided with increased volcanic activity. Empirical evidence to support paleoenvironmental reconstructions in south Iceland is fragmentary, however. We use the physical characteristics of the lavas on the nunataks to reconstruct the ice surface profile over Katla at the time of eruption. Further, we discuss the possible influence of deglaciation and unloading on the Katla magmatic system in facilitating this phreatoplinian eruption.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Historical small-scale phreatic eruptions at Milos Island (Greece) as seen from geological and archaeological investigations

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Milos is one of the four volcanic fields of the South Aegean Volcanic Arc. The youngest volcanic activity in this area (Fyriplaka tuff ring andassociated lava flows) manifested around 110 to 70 ky BP. A large high enthalpy geothermal field has been present in the East Milos at least since200 ky BP. Hydrothermal fluids circulation induced an extensive alteration of the volcanic deposits outcropping in this area, creating favorableconditions for the occurrence of hydrothermal (phreatic) explosions. We aim to understand the physical dynamics that led to the extensive Late Roman Age phreatic explosions in the East Milos area. A large number of Late Roman (3rd-4th century) pottery fragments has been observed at the base of the explosion breccias of the phreatic cones. Clusters of spectacular phreatic craters exist along the NW direction These craters have very limited diameter (around 20-30 m) and contain the Roman pottery. The depth of explosions is always less tha 40 m, clustering around 20 m. We calculated the energy of explosions and we propose cavitation of a water saturated system as explosion mechanism, probably triggered by seismic energy coming through the hydrothermal system

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Off-Rift Subglacial Volcanism in Iceland's Western Volcanic Zone: Hvalfell Analysis.

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Hvalfell, located in the Western Volcanic Zone (WVZ) of Iceland, formed during the Weichselian glaciation and provides a case study for subglacial volcanic processes. This research evaluates magma evolution, volatile contents, and environmental conditions during its formation through field mapping, geochemical analyses, and comparative studies with nearby formations, including Ármannsfell, Mosfell, and Sandfell í Kjós, to better understand interactions between volcanic and glacial processes. Field data showcases a transitions from subglacial pillow lavas to subaerial lava flows, suggesting a change in eruption dynamics. Observations indicate Hvalfell lies on an older unit of pillow basalts, with another nearby pillow basalt unit that may be geologically connected, separated by a fault system. Evidence of southwest-directed glacial flow is supported by deposits in the gully leading from Hvalfell. Electron microprobe (EMPA) analyses reveal variations between two distinct magmas. The older unit shows higher MgO (up to 9.0 wt%) and lower K_2O, indicating a more primitive melt, whereas Hvalfell's glass exhibits lower MgO (7.75 wt%) and higher K_2O, suggesting more evolved magma. Fourier transform infrared (FTIR) analyses of volcanic glasses provide additional insights into volatile contents, with data indicating melt compositions and degassing behavior consistent with subglacial eruptive environments. Comparative geochemical data reveal significant differences in mantle-derived melts and magma storage conditions. Rare earth element (REE) analyses show enrichment in light REEs and inclined patterns (La/LuN > 2.0), indicative of partial mantle melting with limited crustal assimilation. These findings align with models of off-rift magmatism influenced by localized mantle anomalies.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

New Perspectives on Ice Forcing in Continental Arc Magma Plumbing Systems

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Determining how and why eruptive outputs are modulated by the loading and unloading of ice is key to understanding whether ongoing and accelerating deglaciation across mid- to high-latitudes will impact future activity at many volcanoes. Here, we address two central questions. First, does decompression of the upper crust during rapid thinning of ice sheets propel increases in eruption rates? Second, does surface loading during ice sheet growth, followed by rapid unloading during deglaciation, promote changes in magma storage conditions and compositions within the underlying magma plumbing systems? To provide new perspectives on these questions, we address the mechanics and dynamics of ice sheet-arc magma plumbing system interactions at a regional-to-local scale within the Andean Southern Volcanic Zone. Here, piedmont glacier lobes, forming the northernmost extension of the Patagonian ice sheet, have enveloped dozens of large, active, composite volcanoes as these glaciers reached local thicknesses of nearly 2 km during the local Last Glacial Maximum (LGM) between ~35 and 18 ka, before retreating rapidly between 18 and 15 ka. Our multi-faceted review features a synthesis of existing and new field observations, laboratory measurements, and numerical simulations. Advances in $^{40}Ar/^{39}Ar$ radioisotopic and ^{3}He surface exposure geochronology, in conjunction with geologic mapping, facilitate

reconstructions of volcanic eruptive histories spanning the last glacial-deglacial cycle and in places provide constraints on the thickness of ice at specific time slices. The magnitude and geometry of the glacial loading and unloading is captured in a climate model-driven numerical simulation that reveals spatial and temporal heterogeneities in the configuration of the northernmost Patagonian ice sheet retreat. Geological observations including dated moraine complexes, dated lava-ice contact features, and glacial erratic boulders at high altitude on volcano slopes, are consistent with this model. Deep valleys imply intense localized erosion on volcano flanks, and deposited sediment in nearby floodplains implies narrow regions of rapid sediment deposition. These observations, in conjunction with dated lava flows, provide constraints on rates and patterns of crustal loading and unloading by sediment redistribution. The ice loading model, cone growth, and a sediment redistribution history inform numerical simulations of intra-crustal stress changes below the volcanic arc in response to the ice-driven and sediment-driven changes. In turn, the modeled surface loading is central to designing numerical simulations of magma reservoir responses to intra-crustal stress changes beneath the volcanoes. Following periods of subdued volcanic output, upticks in eruptive rates are found at three volcanoes during, or shortly after, the LGM. A numerical magma chamber model suggests that this behavior could be the result of a delicate balance between the timescales of magma cooling, the rate of magma recharge from depth, and viscous relaxation of surrounding crustal rocks. Depressurization of the crust increases eruptive mass flux to the surface only if: (1) the rate of recharge just outcompetes the rate of cooling, (2) the rate of recharge is barely large enough before loading to overcome viscous relaxation of overpressure by creep around the chamber, and (3) magmas are volatile undersaturated, and exsolve volatiles via second boiling during the long repose associated with the high ice loads that precede rapid deglaciation. Existing and newly developed thermobarometers that constrain magma crystallization and storage depths can be applied to eruptive products spanning a glacial-deglacial transition, such that not only secular changes in rates of volcanic eruption, but also changes in the depths of pre-eruptive magma storage and in magma composition can each be interpreted in the light of intra-crustal stress changes associated with glacial loading and unloading.

Theme: 3. Volcanic processes

Session 3.3: Volcano interactions with water or ice

Allocated presentation: Poster

Newly identified hydromagmatic volcaniclastics of Isla Guadalupe, Mexico

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The geology of Isla Guadalupe – located astride an abandoned spreading center west of Baja California – was reconnoitered in the 1960s–1970s. Mapping showed the island to comprise two overlapping shield volcanoes overlain by a younger flank/fissural series; both stages span basalt to trachyte compositions. However, while that mapping also identified pyroclastic deposits, the nature of such rocks and the eruption(s) that formed them have thus far been unexplored. This work reports on a 2024 field campaign that studied these rocks in greater detail to ascertain the dynamics of their emplacement. The volcaniclastics are diverse in character, including, e.g., (a) white, massive matrix-supported ash tuffs; (b) yellowish, grain-supported, coarse pumice deposits with diffuse grading and occasional m-scale thicknesses; and (c) finely bedded, gray-black, occasionally cross-stratified, grain-supported ash and lapilli. The latter often host lenses of coarser pumice lapilli. Lithics and crystals are common accidentals in all deposits. Multiple deposit types can be found within a single stratigraphic sequence, e.g., one section grades upwards from gray-black ash and fine lapilli to a ~0.5 m thick pumice lapilli unit, overlain by a capping series of gray-black ash beds. We infer that many are hydromagmatic deposits, previously unreported at Isla Guadalupe. Differences in grain size and componentry likely reflect different eruption styles associated with magma-water ratios that varied from “wetter” (tuffs, bedded ash surge deposits) to “dryer” (i.e., more magmatic; pumice lapilli airfall(?)), even as discrete phases within a single eruption.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

Astronomically forced global volcanic eruptions and their climatic feedbacks

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Volcanism plays a crucial role in shaping Earth's surface system and influencing human civilization. However, the study of long-term volcanic periodicity and its climatic feedback is complicated by the uneven preservation of eruption records. By analyzing the volume of global volcanic eruption with an ejected magma volume ^{3} 0.1 km^3 as a proxy, our statistical investigation identifies significant periodicities of ~23, 41, and 100 thousand years, correlating with Milankovitch cycles and associated climate change. Notably, a transition from a dominant 41-kyr cycle to a 100-kyr cycle is observed across the Mid-Pleistocene Transition. The strong coherence between change rates of global mean surface temperature and volcanic eruption volumes suggests that warming during deglaciation enhances the frequency of volcanic eruptions, indirectly paced by orbital forcing. These findings imply a direct causal link between cyclical climate change and periodicity of volcanic eruptions, and demonstrate that large volcanic eruptions are more likely to occur at the onset of deglaciation, potentially contributing to positive feedback mechanisms in global warming through the release of volcanic carbon. Understanding past volcano-climate interactions is thus crucial for predicting the upcoming rhythm of volcanic activities and anticipating the long-term impacts of both natural and anthropogenic climate drivers.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

The AD 79 Vesuvius eruption revisited

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The fall and pyroclastic density current deposits stratigraphy of the AD 79 eruption of Vesuvius is comprehensively reappraised, yielding a more accurate picture of how the 31 hr duration eruption evolved with time and space. The Plinian fall deposit was one of the earliest to be treated with a modern volcanological approach. Twelve lithostratigraphic units within the pumice fall sequence (7 in the 'White Pumice Deposit'; 5 in the 'Grey Pumice Deposit') are distinguished by variations in grain size and the ratio of lithic to juvenile clasts (based on 459 samples) and show that the Plinian plume fluctuated between 14 and 34 km in height, depositing 6.4 km^3 of tephra in 17 h. Five post-Plinian lithic-rich fall layers are recognized, each recording a subPlinian event that persisted for several tens of minutes. Seventeen pyroclastic density currents (PDCs) formed before, during, and after the Plinian phase, and are recorded by 27 defined and mapped lithostratigraphic units 15 of which show significant lateral and vertical variations in lithofacies (417 samples analysed). The minimum total volume of PDC deposits is 1.25 km^3. The post-Plinian phase spanned 14 h. Proximal lithic breccias 30 m thick may record subsidence at source. The most powerful PDC (p-PDC 13) had the greatest runout. As it waxed its footprint gradually increased radially, reaching a distance of 25 km from source and surmounting hills >800 m above sea-level. The eruption ended at 8.05 pm on the second day, leaving behind a widespread trail of devastation.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

Improving the longer-term record of explosive volcanism in the Mexico City region

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The Mexico City region is home to over 25 million people, making it one of the largest populations in the world. This densely populated megacity is surrounded by numerous, active, long-lived (polygenetic) volcanoes, such as Popocatépetl and Nevado de Toluca. It also comprises a highly active volcanic field which includes over 200 shorter-lived (monogenetic) volcanoes, visible at the surface today. Due to being a fiercely built-up area, the eruptive histories of these hazardous volcanoes are poorly constrained, covering only the largest eruptions over the past 40,000 years. This talk will present new research findings which provide a near-complete record of explosive volcanism which has impacted the Mexico City region over the past 400,000 years, a tenfold increase on what is currently known. This record contains eruptions from both polygenetic and monogenetic volcanoes

as well as more distal caldera volcanoes from outside of the Mexico basin and Mexico. Through the use of a deep (over 500 m) sediment core, collected from a lake on the south-eastern edge of Mexico City (Lake Chalco), combined with new fieldwork, geochemistry and geochronology; a detailed volcanic stratigraphy of diverse eruptions impacting the Mexico City region is reconstructed over a timeframe that is comparable to the lifetimes of many of the surrounding volcanoes. Alongside presenting new chronological information, this research delivers the first long-term eruptive history of volcanic activity affecting the Mexico City region and an accurate frequency of impactful eruptions on the megacity over the past 400,00 years.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

New 1-to-100k scale geology map embracing volcano geology in the Harrat Lunayyir, NW Saudi Arabia

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Along the western margin of the Arabian Peninsula, at least 19 monogenetic volcanic fields have been identified. The Saudi Geological Survey (SGS) is currently developing a comprehensive volcanic hazard interface for both scientific research and other end-user purposes. This initiative involves systematically compiling all available multi-sourced geophysical data and conducting real-time complex geophysical monitoring (including seismic activity, gas measurements, water temperature, and chemistry). This effort depends significantly on the establishment of an intricate volcanic geology interface. The integration of nearly four decades of accumulated but dispersed information is expected to create a valuable resource. Saudi Arabia offers a 1-to-250k geology map series through the National Geological Database; however, the geological data on the volcanic architecture of its numerous volcanic fields is quite general and does not align with current understandings of monogenetic volcanism. For the northern part of Harrat Rahat, near Al Madinah, geological maps have been produced by the USGS-SGS at scales of 1-to-75k and partially at 1-to-50k. Since the 2009 eruption unrest in Harrat Lunayyir, located northwest of Al Madinah near the Red Sea coast, geological mapping has accelerated to a 1-to-100k scale with a goal to provide a volcanic stratigraphy map based on direct observations. The heightened interest in regional tourism development, combined with the area's recent volcanic activities, has prompted efforts to complete detailed geological maps with a strong focus on volcanic geology. This aligns well with SGS's objectives to finalize geological mappings of its young volcanic fields.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

A New Subaerial Record of Explosive Volcanism and Tsunami along the Tonga Volcanic Arc, Tonga, SW Pacific

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Despite frequent volcanic activity, the eruption history and hazards of the Tonga Volcanic Arc remain poorly constrained due to the small landmass of the Tongan archipelago (~750 km^2) and limited Holocene subaerial exposures. This study presents a new tephrochronological record of explosive eruptions and tsunami events in Tonga, based on swamp coring across uplifted and inhabited islands east of the volcanic front and downwind for high-altitude winds. These swamps, formed in lagoon basins isolated after the mid-Holocene high sea level stand, preserve tephra layers well compared to the surrounding tropical soils. Coring revealed multiple tephra layers within humic sediment or peat, with radiocarbon dating providing a timeline of eruptions within the last 6500 cal. Years B.P. Geochemical analysis indicates explosive eruptions of basaltic andesite to dacite composition (55-69 wt.% SiO_2), with some exhibiting compositional changes during the eruption. Preliminary results suggest several significant eruptions, including two from Hunga volcano (AD 418-645 and AD 1119-1279), likely generating tsunamis, as indicated by sandy layers with shell fragments and volcanic particles. Notably, the tephra properties of the AD 500 eruption closely resemble the 2022 Hunga eruption, though deposit thicknesses suggest it was a larger event. Further analysis suggests another major eruption between AD 1000-1300, likely from Tofua or Kao, with widespread impact. This study improves the understanding of volcanic and tsunami hazards, crucial for assessing future risks, especially on Tongatapu Island, where >70% of Tonga's population resides. Ongoing work will refine eruption chronologies and correlations and link findings with archaeological records.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

New Insights into the history of explosive volcanism of the Kolumbo Volcanic Chain. IODP Expedition 398 Hellenic Arc Volcanic Field

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Submarine eruptions, such as those from the Kolumbo Volcanic Chain (KVC) in the South Aegean Volcanic Arc, present a range of hazards. Kolumbo Cone (7 km NE of Santorini) is the largest submarine edifice in the KVC and has one well-constrained eruption in 1650 CE. This eruption resulted in the release of toxic gases, earthquakes, volcanic explosions and a tsunami. Over 70 people died and there were significant impacts to the population of Santorini. Older edifices are identified in seismic profiles of Kolumbo Cone. However, they are poorly constrained, and studies of the KVC eruptive history are challenging. IODP Exp 398 provides a unique opportunity to unravel the history of the KVC by drilling proximal to Kolumbo Cone. Here, we present new tephrostratigraphic and geochemical constraints of the KVC. Tephra layers are geochemically characterised using major and trace elements of the volcanic glass. At Site U1593, we identify at least 10 eruptions from the KVC intercalated with eruptions of the Thera Pyroclastic Formation (TPF) and at least three prior to the TPF. These eruptions range from basaltic-andesite to dacite, as well as the high-silica rhyolite compositions previously known. The trace element chemistry is not comparable to modern Santorini and instead, for example, has higher Ba/Y (>20), lower Zr/Nb (<15). The eruption ages are constrained using sedimentation rates based on the established ages of Santorini eruptions. The new eruptive history can be used for eruption frequency and volcano monitoring, necessary for crisis response and eruption response planning.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

Revised chronostratigraphy of explosive eruptions at Mt. Pelée volcano (Lesser Antilles) in the last 5 kyr: Tephra dispersal and implications for volcanic hazard assessment

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Mt. Pelée in Martinique is one of the most active volcanoes in the Lesser Antilles with several dome-forming and sub-Plinian to Plinian eruptions over the last 5 kyr. Historical volcanic events include two minor phreatic eruptions in 1792 and 1851, and two dome-forming eruptions that caused a total of 30,000 fatalities in 1902 and the evacuation of 10,000 people in 1929. The prehistoric activity of Mt. Pelée volcano has been extensively studied through geological mapping, tephrostratigraphy, geochronology, petrology, and geochemistry. However, these past eruptions are not all reconstructed with the same level of precision, ranging from a brief description of poorly-preserved deposits to a detailed time evolution of the reconstructed eruption source parameters. Here, we present a revised chronostratigraphy of the explosive activity during the last 5 kyr based on new field data, a unique collection of 120 radiocarbon ages, and detailed sedimentary and stratigraphic investigations. Our results confirm the occurrence of six Plinian eruptions, with a variety of opening phases ranging from a phreatic eruption to violent laterally directed explosions, and nine dome-forming eruptions. All these eruptions produced at some stage dense and/or dilute pyroclastic density currents (PDCs) around the volcano. Our reconstructed isopach and isopleth maps allow us to quantitatively constrain the areas impacted by tephra fallout and PDCs. We discuss how our results on eruption frequency and deposits distribution fit into the revised hazard map of Mt. Pelée volcano.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

Eruptions, unrest and disaster: a historical approach to eruptive histories in the Eastern Caribbean

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While eruptive histories are preserved in deposits the impacts of eruptions on communities at risk is more often preserved in written or oral histories. These provide critical insights into the actual versus the assumed impact of eruptions, and help to understand 'absences' in the stratigraphic record, and the conditions where eruptive histories might lead to disaster. Disaster is hard to define. But, there is general consensus that for groups of people located in a similar geographic area disaster usually happens when multiple people experience significant disruption, loss or hardships as a direct or indirect result of a hazardous physical event. Using this starting point, we examined both eruptions and non-eruptive events (unrest) and focussed on the responses to *threats* of disaster, as well as its aftermath. The historical approach affords us unusually frank contemporary insights into different views on the evolving situation through (field) notebooks, personal and official correspondence. This survey of written and oral histories in St. Vincent and Montserrat demonstrate the strong local and regional importance of periods of magmatic unrest, and periods of relative inactivity that punctuate longer cycles of eruptive activity in creating conditions for disaster. In these times vulnerabilities are amplified or dissipated, often through a lack of effective decision-making. To improve future response we argue eruptive histories need to more clearly account for the unusual and challenging capacity that volcanoes have to 'threaten disaster' during eruptive cycles. This can be done by the integration of historical, oral and stratigraphic histories.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

Addressing the challenges and knowledge gaps in reconstructing eruptive behaviour in volcanic island settings

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A major proportion of Earth's volcanoes lie in island settings: 43% of the global arc length comprises island volcanoes, alongside numerous rift and intraplate volcanic islands. Hazards posed by these volcanoes are modified by interactions with water, and the scale of their eruptions is diverse, with island sites likely responsible for many of the largest Holocene eruptions. Volcanic islands also present challenges for monitoring and hazard mitigation, given reduced scope for ground- and satellite-based observations, and often isolated communities or fragmented communication networks. Such settings thus warrant attention, yet our capacity to reconstruct past behaviour at island volcanoes – information vital to more informed risk management strategies – is directly hindered by their geographic environment. Subaerial exposures are limited, and submarine archives of past activity, which may be more complete than in many continental environments, are challenging to access. This has led to a significant information gap: in many parts of the western and southern Pacific, knowledge of Holocene eruptions is over two orders of magnitude lower than that in well-studied continental areas, on a regional scale, and effectively absent for many areas. Here, we explore these challenges using a variety of case studies, with a particular focus on Indonesia and the SW Pacific. The complexity of eruptive behaviour, and the potential for cascading hazards, is connected to island size. In turn, this presents difficulties for reconstructing past activity and for sampling and interpreting deposits, calling for new strategies to evaluate past activity and address broader knowledge gaps.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Talk

New insights into the Santorini Amorgos Tectonic Zone from Maria S. Merian expedition 132

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The Santorini Amorgos Tectonic Zone has been the setting of some of the most severe natural disasters in southern Europe in historic times. Both explosive volcanic eruptions and earthquakes related to back-arc rifting have caused destructive tsunamis. The enigmatic location of the volcanic arc far behind the subduction zone both controls and is controlled by back-arc rifting. With new geophysical and seafloor imagery data we constrain the geological processes that control the hazard potential of the area. Reflection seismic data show several generations of explosive eruptions of Kolumbo Volcano near the northwestern termination of the Christiana-Santorini-Kolumbo system. In conjunction with bathymetric data they reveal that the volcanoes have been affected by slope movements and erosion during the emplacement of pyroclastic flows. New 3D seismic data document the structural configuration of part of the seismogenic Amorgos fault zone, with sharp single fault scarps at the centre of the fault close to the southern tip of Amorgos, and more diffuse seafloor deformation towards the southwestern terminations. These significant differences along strike might help to explain the vastly different tsunami run-up heights on surrounding Aegean islands reported by eyewitnesses in 1956.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Unravelling Pleistocene-Holocene Plinian eruption hazards and dynamics from detailed lithostratigraphy, radiocarbon dating, and chemical-microtextural analyses at Pico de Orizaba Stratovolcano and Los Humeros Caldera, Eastern Mexico

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The most intense explosive volcanism in eastern Mexico spans from the Pleistocene to the Holocene and includes recent activity (1700-1800 CE and 2.8 ka, correspondingly) from the andesitic-dacitic Pico de Orizaba Stratovolcano (PO, 5630 m-altitude) and the basaltic-rhyolitic Los Humeros Caldera (LHC, 2800 m-altitude). These two systems have complex eruptive histories, featuring stages of numerous Plinian events bounded by episodes of edifice-collapse-driven debris-avalanches (PO) and caldera-collapse-driven ignimbrites (LHC). While the rare collapse stages are well-documented, the more frequent inter-collapse explosive eruptions and associated hazards are less understood. We conducted comprehensive lithostratigraphic mapping, radiocarbon dating, and chemical and microtextural analyses to reconstruct the eruptive source parameters, intensities, magnitudes, hazards, and dynamics of three of the largest Plinian episodes from PO and LHC. Our findings indicate that PO can produce VEI-4 Plinian eruptions with column heights of 25-28 km, fall deposits of 0.04-0.1 km^3 dense rock-equivalent (DRE), and mass discharge rates of 10^8 kg/s. In contrast, LHC is capable of catastrophic VEI-6 Plinian eruptions with column heights reaching 35-40 km, fall deposits of 1-5 km^3 DRE, and discharge rates of 10^8–10^9 kg/s. In both systems, Plinian columns are interspersed with pyroclastic density currents driven by summit dome-collapse (PO), outgassed lava-plug explosions (LHC), column-collapse, or hydromagmatic processes. Microtextural and chemical analyses of banded PO scoria and LHC pumice clasts suggest that magma mixing or mingling commonly powers explosive volcanism in eastern Mexico. In the event of reactivation, these systems could threaten up to two million people.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Contrasting Emplacement Mechanisms of Two Debris Avalanches in Banahaw Volcano, Philippines revealed by Morphometric Analysis and Field Evidence

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Volcanic flank collapses have resulted in the largest terrestrial landslides known as volcanic debris avalanches. Morphological signatures include a horseshoe-shaped breach in the source area and associated hummocky deposits, seen in many Quaternary volcanoes including Banahaw in the Philippines. The transport and depositional mechanisms of the Lucban and Lucena debris avalanches at Banahaw volcano were deduced using morphometric assessment and field evidence. A total of 801 and 370 hummocks were delineated for the Lucban and Lucena deposits, respectively. Lucban hummocks exponentially decrease in size with distance, while Lucena exhibits no trend. In the Lucban, clusters of hummocks are displaced at 60°-90° relative to the flow direction, but the majority are aligned parallel (0° to 30°) along the runout path. In contrast, Lucena hummocks are notably displaced 60° to 90°, where flow transitions from an ESE to a SSE direction, while distally, hummocks are displaced 0° to 30°, reflecting further lateral spreading and extension towards the coast. The behavior of the Lucban avalanche may be due to limited substrate entrainment, resulting in consistency of rheology and fragmentation patterns during transport, while competent avalanche material or high basal shear strength may have caused localized compression despite the dominantly extensional stress regime. The irregularity of spatial distributions in size and displacement of the Lucena hummocks may have been the cumulative effect of local topography and slope of the runout path, as well as a shift in flow character due to increasing amount of matrix in the collapsing mass during transport.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Reassessment of the eruptive history of the Atitlán volcano: towards hazard evaluation

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Guatemala ranks as the sixth nation in the world with the most significant volcanic threat and is among the most vulnerable and least resilient to natural disasters. The Atitlán volcano is considered the third most hazardous volcano in the country, following Santiaguito and Fuego. It has been active in historical times, with at least six eruptive episodes documented since the arrival of the Spaniards. The most recent episode began in 1826 and concluded in 1856. Approximately 70,000 people reside within a 10 km radius of the Atitlán volcano, mainly in the municipalities of Santiago Atitlán and San Lucas Tolimán. Due to the communities' low resilience to natural hazards, the Atitlán volcano is ranked first in the global volcanic risk index. Understanding the volcano's historical eruptive activity and its associated products is essential to mitigating the potential impact of a future eruption. Previous studies in the region have primarily focused on the major eruptions of the Atitlán caldera and the development of a regional geologic map of Quaternary and Tertiary deposits, often without detailed stratigraphic distinctions. This work reassesses the Holocene eruptive history of the Atitlán volcano, incorporating new data on stratigraphic relationships, deposit distribution, radiocarbon (C14) dating, petrology, and geochemistry. These findings are crucial for establishing future eruptive scenarios in case of volcanic unrest, identifying areas potentially impacted by pyroclastic deposits, and contributing to an updated volcanic hazard assessment.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Geochronology of the potential first eruptive phase of the Monte Vulture Volcano (Basilicata, Italy).

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The Monte Vulture stratovolcano is located in the central part of the peninsula, 110km east of Naples. This volcanic complex is peculiar among Italian volcanoes found at the intersection of faults, at the eastern flank of the Apennine chain, where the Apennine thrust front overlies the Apulian carbonate platform (Boenzi et al. 1987). The geodynamic as well as eruptive history and geochemistry evolution of the complex still remain poorly understood. The eruptive products are silica undersaturated including carbonatite, which is uncommon in Italy. Up to now only a handful of studies have been published on the dating of its products and many questions remain unanswered in particular concerning the volcano's activity during the early-middle Pleistocene. In the frame of this contribution, we will present the first results of a new $^{40}Ar/^{39}Ar$ dating effort focused on the early activity of the Monte Vulture Supersyntem. Our new data reveal a more complex than expected chronostratigraphy of the oldest phase of activity named in literature the Foggianello Syntem (Villa and Buettner, 2009). Our new high precision $^{40}Ar/^{39}Ar$ on single-crystal dating demonstrate that the beginnings of the volcanic activity is marked at least by two major ignimbritic eruptions (Fara d'Olivo), respectively dated at 784.4±1.0ka and 777.2±2.4ka. After a period of about 40ka of quiescence a new period of explosive activity occurred at around 740±2.0ka, shortly followed by an effusive phase (Spinoritola) dated at 732.0±1.0ka. Finally, the youngest explosive activity here, the Campanile subsyntem, corresponds to pumice fall deposits dated between 708.9±1.8ka and 700.2±1.3ka.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Age of the pre-1883 caldera-forming eruption of Krakatau, Indonesia

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Krakatau is one of the most famous volcanoes on Earth due to its deadly caldera-forming eruption in 1883. During the eruption, about 20 km^3 of pyroclastic material were erupted, and a caldera with diameter of 7 km was formed. The Volcanic Explosivity Index (VEI) of this eruption is 6, which is among the most violent volcanic events in modern history. The combined effect of pyroclastic flows and tsunamis along the coast of the Sunda Strait had disastrous results: more than 36,000 victims. Works of Steve Carey, Haraldur Sigurdsson, and Jennifer Beauregard (2001) have shown that during the Holocene, before 1883, Krakatau produced several strong explosive eruptions, one of which was caldera-forming (deposited thick layer of locally welded ignimbrite). We were able to find in a southern cape of Lang (Panjang) Island of the Krakatau Archipelago and date (using the ^{14}C AMS method) the sandy paleosol lying directly below the 10 m-thick deposit of welded ignimbrite of the pre-1883 caldera-forming eruption: 6930-6820 BP. The dated ignimbrite probably corresponds to Unit B of Beauregard (2001), and the obtained age is consistent with her date of 8000 BP for stratigraphically lower (older) pyroclasts from the same area. This result indicates that recurrence frequency for caldera-forming eruptions of Krakatau can be estimated as ~7000 years (rather ordinary for volcanic arcs). Definitely Krakatau did not produce a large caldera-forming eruption ca. 400 or 500 AD as was suggested by Wohletz (2000), basing on old epics and Chinese history.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Postglacial eruptive history at Laguna del Maule, Chile, used to reconstruct timing of paleolake filling and catastrophic demise

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Postglacial eruptive history at Laguna del Maule volcanic field (LdM) on the Argentina-Chile border (36° S) was established using tephrostratigraphy and mapping to document >100 eruptive events from vents near the eponymous Laguna during the last 16 kyrs. Largest of these was a 15 ka Plinian eruption of high-silica rhyolite from a now-submerged vent near the center of the present-day lake. Explosive eruption of >35 km^3 of pyroclastics deepened the basin below its natural outlet of 2,150 m, resulting in subsequent formation of a basin-bottom lake. A later eruption ~11.2 ka from a vent 5 km away produced a rhyolitic lava flow that dammed the outlet, enabling the lake to fill 200 m higher than its original natural threshold. Silt accumulating in the lake bottom preserved much of the LdM postglacial explosive history as intercalated tephra layers, now exposed at different elevations around the basin. Combined with radiocarbon dating, these tephra-silt sections capture the history of the deepening lake until it reached its highstand at an elevation of 2,350 m. Breaching of the lava dam resulted in a catastrophic flood down the Río Maule, leaving behind a distinct highstand terrace around the basin. Tephrostratigraphy shows the paleo-Laguna del Maule began filling as much as 4,000 years before its outlet was dammed by lava, after which it reached its highstand over a period of ~2 kyrs, drained catastrophically ~9 ka, but remained a lake more than 20 meters higher than the initial blockage for at least another 2 kyrs.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

How to reconstruct the eruptive history of the Coconucos Volcanic Chain (Colombia) to assess the volcanic hazards?

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The Coconucos volcanic chain (CVLC) located in the Cordillera Central of Colombia (CCC) with a direction N 25° E, is considered as a resurgent volcanism of the 30 km diameter Paletará caldera (2.4 My). The CVLC is 6.5 km long, presents 15 eruptive centers aligned N39°W. In addition to the Puracé volcano, to the NW, one of the most active volcanoes in Colombia (last eruption 1977), there are Piocollo, Curiquinga, Calambás-Paletará, Quintín, Shaka (upper, middle and lower), Killa, Machángara, Pukará, Pan de Azúcar, in the SE end, and the adventitious cones of Amancay and Piki. Since 2015, the Popayán Volcanological and Seismological Observatory (OVSPO) has recorded changes in the behavior of the CVLC, concentrated mainly in the NW sector where Puracé, Piocollo and Curiquinga volcanoes are located. The changes detected consist of an increase in seismicity in this sector, deformation, changes in the hot springs around the chain, fumarolic activity of the Puracé volcano and, on March 29, 2022, a small emission of ash, of phreatic origin, in the crater of the Curiquinga volcano. Although the volcanic hazards in Colombia are established by reconstructing the volcanic history (10,000 years), historical activity and monitoring, for the CVLC takes into account its origin as resurgent volcanism in the Paletará caldera and the eruptive history of the Puracé volcano, which is related to other previous volcanic centers (Chagartón caldera and Prepuracé) and presents a different behavior to the other eruptive centers in the chain.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Late-Stage Volcanism in the Galápagos: A Distinct Mechanism from Hawaiian Rejuvenated Volcanism

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Whereas rejuvenated volcanism at Hawai'i has been clearly defined geologically, geochemically, and temporally, comparable late-stage behavior at other archipelagos deviates from Hawai'i's behavior. Unlike Hawai'i, the oldest Galápagos islands do not exhibit a clear, significant hiatus or erosional period, widely variable eruption rates, or distinct shield-building and post-shield phases. For instance, volcanism at Santa Cruz began ~1.6 Ma and continued to ~200 ka, when it focused along an E-W fissure system. The southern flank lavas erupted <200 ka, with morphologically youngest lavas on the NNW flank. Faults crosscutting the southern flank formed 200-33 ka. San Cristóbal was constructed between 2.1 Ma and ~300 ka, is dominated by ENE-trending faults and fissures, and includes a young volcanic field along its northern coast, active from 174 to 5 ka. Floreana's alkaline lavas erupted from 1.6 to 0.03 Ma, with no evidence of an eruptive hiatus. Gravity surveys prove that neither San Cristóbal nor Santa Cruz ever had large calderas like the western shields. The youngest lavas on all three islands exhibit heterogeneous compositions that overlap those of older lavas. At Santa Cruz and San Cristobal, older volcanism is weakly alkalic, shifting to alkalic and MORB-like tholeiites in younger lavas. Most eastern Galápagos volcanoes were formed near the Galápagos Spreading Center, located <100 km from the plume >3 to 1 Ma. Formation of these volcanoes under the GSC's influence, coupled with emplacement on thin, near-ridge lithosphere may have influenced their morphology and evolution, resulting in late-stage activity distinct from Hawaiian rejuvenated volcanism.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Age-clustered eruptive activity at La Palma (Canary Islands) during the last 4000 years: Evidence from paleomagnetic dating

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The detailed knowledge of timing and dynamics of pre-historic eruptions is pivotal for volcanic hazard assessment. This is most relevant for inhabited lower slopes of active basaltic volcanoes such as La Palma (Canary Islands), where the 2021 Tajogaite eruption caused severe destruction. We paleomagnetically investigated eight La Palma Holocene eruptions which are currently loosely constrained either by few radiometric (K/Ar and ^{14}C) ages, or by stratigraphic/archaeological evidence. The paleomagnetic directions gathered from 28 sites (300 oriented cores) were compared with updated reference models of the paleo-secular variation of the geomagnetic field direction during the Holocene. Overlapping paleomagnetic directions from the Fuego and La Fajana lava flows, along with geologic and geochemical evidence, imply that the two flows were emplaced during the same 2000–1727 BC eruptive event. Single paleomagnetic age windows - consistent with and narrower than available ^{14}C age intervals - were obtained for three lava flows. Conversely, three eruptions yielded multiple age solutions. Moreover, our data show that the flanks of the pre-historic San Antonio scoria cone are almost totally covered by pyroclastic products of the nearby AD 1677 Fuencaliente eruption. The updated chronologic framework of the pre-historic volcanic activity at La Palma demonstrates that the past four kyr are characterized by an early period with low-frequency eruptions (three lava flow eruptions between ca. 2000 BC and 300 BC), followed by a ca. 1000 yr-long quiescence period, and by a subsequent clustering of nine events during the last 1100 yr (about one eruption per century).

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Paired Zircon and Allanite Dating of late Pleistocene-Holocene Rhyolites in the Mono Basin, Eastern California, USA

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The ~30 high-silica rhyolite domes and flows of the 15 km-long Mono Craters volcanic chain are some of the youngest rhyolitic volcanoes in the western United States. Their ages range from ~40 ka to 0.7 ka with a total erupted volume of ~8.5 km^3 and distinctions based on mineralogy (biotite, orthopyroxene, or fayalite-bearing) and crystallinity. Ion microprobe ^{238}U-^{230}Th dating of allanite and zircon crystal surfaces was previously used to date the final crystallization period of the ~40–20 ka biotite-bearing domes and younger ~12–9 ka orthopyroxene-bearing domes. We present new ^{238}U-^{230}Th dates for the fayalite-bearing and sparsely porphyritic Mono domes. The fayalite-bearing domes are compositionally indistinguishable despite having the widest spatial distribution of all the Mono domes, with ~12 km separating the northernmost from the southernmost dome. Fayalite-bearing whole-rock compositions are tightly constrained from 76-77 wt.% SiO_2 and represent extremely fractionated (Sr <8, Ba <20 ppm) melts. Glass compositions from the fayalite-bearing domes return rhyolite-MELTS quartz + 2 feldspar storage pressures of ~7 km. Results suggest that all nine fayalite-bearing domes are essentially the same age and erupted ~6 ka. At least one dome from the sparsely porphyritic group appears older with a U-Th zircon-allanite date of ~20 ka. This dome, as well as the older biotite and orthopyroxene-bearing domes, all contain distinctly different whole-rock trace-element compositions than the younger fayalite-bearing, sparsely porphyritic, and aphyric domes. By further constraining the eruptive history of the Mono Basin, we improve our understanding of volcanic hazards in eastern California.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Relationship between caldera structure and associated pyroclastic flows: The case of the Atosanupuri volcano, eastern Hokkaido, Japan

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Atosanupuri volcano, located in eastern Hokkaido, Japan, is one of the post-caldera volcanoes of the Kutcharo caldera volcano. The volcano consists of the somma, the inflectional caldera (6 * 3.5 km in total length: Atosanupuri caldera) and several lava domes. Its activity started after the 40 ka Kutcharo pyroclastic flow I eruption: the somma lavas extruded and a large pyroclastic flow (Atosanupuri pyroclastic flow: Ap) erupted to form the Atosanupuri caldera. Several lava domes were then built in and around the caldera. Although it is considered that the Ap eruption was accompanied by the formation of the caldera, its eruption scale and sequence are still unknown. To clarify the whole sequence of the Ap eruption, we investigated the tephra stratigraphy in the distal area and correlated the distal tephra with the proximal Ap deposits based on the petrological characteristics of their juvenile materials. The results show that the Ap eruption was not a single event, but a series of VEI 4-5 eruptions over 10 kyrs (ca. 40 km^3 in total volume), and that three magma systems were active in turn. According to the topographic map made from the 1 m DEM data, the Atosanupuri caldera seems to consist of multiple calderas and craters. This feature is consistent with multiple pyroclastic eruptions: i.e., the Atosanupuri caldera is a composite caldera. The Ap eruption is comparable in scale to the caldera-forming eruptions in general. Therefore, it would be better to re-examine its implication in the caldera cycle of the Kutcharo caldera volcano.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

The Evolution, Recurrence and Behaviour of Monogenetic Volcanism in the Gegham and Vardenis Volcanic Highlands (Armenia)

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The Gegham and Vardenis Volcanic Highlands (Central Armenia) consist of >200 Quaternary monogenetic vents, which are predominantly scoria cones, formed primarily during Strombolian eruptions. Seismic swarms in the Gegham Volcanic Highlands can be linked to an active magmatic system, indicating the possibility of future eruptions, which could pose a threat to Armenia's capital city Yerevan (~20 km SW of Gegham), and its population of 1.1 million people. However, the timing of volcanism in the region is currently poorly constrained and the age of the last eruption is unknown, limiting volcanic hazard estimation. Here we utilize $^{40}Ar/^{39}Ar$ geochronology, geochemistry and statistical modelling techniques to reconstruct eruption timings, recurrence rates and the spatio-temporal evolution of this potentially active monogenetic volcanic field. Field work and whole rock geochemical analysis reveal that past eruptions have produced extensive lava flows, scoria, and spatter, with predominantly basaltic trachyandesite and trachyandesite compositions (51.8 - 63.2 wt. % SiO_2). 31 new $^{40}Ar/^{39}Ar$ ages for monogenetic vents, reveal the timing and recurrence rate of volcanism in the Gegham Volcanic Highlands and provide ages for the youngest volcanic activity in the Vardenis Volcanic Highlands. Results from kernel density estimation reveal areas most likely to experience future vent formation, based singularly on the distribution of previously formed volcanic vents. Spatio-temporal modelling will estimate the location and timing of possible future eruptions. Overall, the findings from this project will contribute to volcanic hazard assessment in Armenia and will improve our understanding of the evolution of monogenetic volcanic fields in post-collisional geodynamic settings.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Eruption chronologies using a new volcanic region system based on tectonic environments

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The IAVCEI Catalog of Active Volcanoes of the World (CAVW) series, published in 22 volumes (1951-1975), was a major founding reference for the "Volcanoes of the World" database, maintained by the Global Volcanism Program (GVP). This series was used to create a volcano organization system of Regions (each volume) and Subregions (chapters), which were modified over time but remained geographical. GVP has developed a new system of volcanic regions accounting for plate tectonics, deployed to the website during 2024, consisting of 139 Regions (Holocene volcanoes in 118, Pleistocene volcanoes in 117). Region names generally include or reference common scientific or geographic names, combined with five category terms indicative of the broad tectonic environment: Volcanic Arc (subduction), Volcanic Rift Province (rifting), Hotspot Volcano Group (mantle plume), Volcano Group (fault/fracture zones), and Volcanic Province (intraplate, back-arc, mixed, or uncertain). These Regions are further organized into 19 Region Groups, which take into consideration both geography and tectonics when possible (e.g. keeping volcanic arcs associated with a single plate together). Having each volcano assigned to a region in the database allows for various queries and applications. Each Region Group webpage has regions shown separately with Holocene and Pleistocene volcano lists, and a chronology of all eruptions included in the VOTW sorted by date. This data is also available in a downloadable spreadsheet, which will allow more detailed analysis of eruption frequency and style within each region along with comparisons between regions.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Reconstructing eruption intensity at Augustine Volcano, Alaska: tephra stratigraphy and componentry of the 750 ybp Tephra M eruption

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Augustine Volcano is one of the most frequently active and highest threat volcanoes in Alaska (Ewert et al., 2018). Eruptions since 1812 have been smaller and less explosive than those from 390-2100 ybp (Waitt and Beget, 2009). We quantify changes in grain size (Pmax, Lmax, Md) and componentry through a 135 cm thick deposit of Tephra M (750 ybp), the thickest in the late Holocene, to assess changes in explosivity within a single eruptive sequence and compare to modern eruptions at Augustine. Tephra M comprises eight sublayers that vary by grain size and/or the abundance of lithic fragments. The basal sublayer is 10 cm of fine lapilli with >20% lithic fragments, consistent with dome destruction and conduit opening. The deposit coarsens to coarse lapilli in the next two sublayers (75 cm), signaling an increase in eruption intensity. This is overlain by 10 cm of ash-coated coarse lapilli (>55 % ash). The uppermost four sublayers (40 cm) of the deposit are ash-poor coarse lapilli, and record cycles of coarsening that we interpret as pulses in eruptive intensity. Using correlations between grain size and plume height (e.g., Eychenne and Engwell, 2024), the coarsest layers of Tephra M suggest eruptive columns reached 20-30 km high. Unlike modern eruptions, we lack direct observations of the eruption of Tephra M, one of the most explosive late Holocene eruptions of Augustine. We reconstruct the eruptive dynamics of Tephra M to compare with modern, lower-explosivity eruptions and highlight key differences in Augustine's variable eruptive behavior.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Toward understanding the geohazards of Huangzuei volcano (Taiwan) from geomorphological mapping, 40Ar-39Ar dating and geochemical constraints

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Although it abuts the northern flank of the Taipei metropolitan area, hazards posed by the 25-km wide Tatun Volcanic Group (TVG) are poorly understood. The Huangzuei complex is one of the younger TVG volcanoes, with well-preserved landforms that comprise three sequences of andesitic flows that radiate northwestward, northeastward and eastward up to six km from a complex horseshoe-shaped, cratered 250-m tall edifice, Mt. Huangzuei. Very high-resolution topography from a LiDAR-based DEM enabled detailed demarcation and characterization of individual flows, including their volumes, thicknesses, and profiles. In our first year of work, we began to constrain the evolution of the volcano *via* ^{40}Ar-^{39}Ar dating and petrologic and geochemical analysis of a dozen samples from key lava flows. The northwestern flow sequence is composed of two flows. Two ^{40}Ar-^{39}Ar dates indicate that eruptions occurred 116.6±2.0 and 128.8±1.8 ka (2s). The as yet undated northeastern flow sequence comprises three distinct flows with pronounced ogives, one atop the other. The eastern flow sequence extends 3 km east and then 3 km north from Mt Huangzuei's summit. It includes five distinct flows and associated levees. The second oldest flow erupted 85.4±2.3 ka. Our initial mapping and dating suggest that the Huangzuei complex has experienced at least three and possibly four eruptive episodes. Two of them are well constrained by petrological and geochemical analyses. We anticipate that samples yet to be collected this year will further constrain the eruptive history of Huangzuei volcano, toward the goal of quantifying its future geohazards.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Estimating Effusive Eruption Volumes to Reconstruct the Volcanic History of Methana, Greece

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Estimating eruption volumes of dormant volcanoes is necessary to understand the activity of volcanic systems in the past and potentially forecast their behavior in the future. Methana Volcano, as part of the South Aegean Volcanic Arc (Greece), consists of at least twenty-two andesitic to dacitic effusive eruptions during the last approximately 2.1 Ma. The last eruption took place in historical times around 230 BCE and produced a ~ 2.5 km-long lava flow. We present a study of effusive eruption volume estimations using the open-source Copernicus DEM GLO-30 in combination with bathymetry data to include the offshore extent of coastal lava flows. Bulk volumes of the effusive phases are converted into their respective dense rock equivalents (DRE) by removing the porosity and voids induced by brecciation, fracturing and degassing during an eruption. The calculated DRE volumes range between 0.1 Mm^3 and ~170 Mm^3 per eruption, with the largest being the afore mentioned historical eruption. The combined DRE volumes for each evolutionary phase indicate a variable activity of Methana Volcano over time with relatively moderate effusive volumes between 0.6-2.1 Ma, lower volumes between 0.4-0.6 Ma and higher volumes for the phases starting around 0.4 Ma and thereafter. The temporal changes in effusive eruption volumes coincide with the activation of different fault patterns in the wider area of Methana Volcano. However, further investigations, including precise dating of Methana´s volcanic products, are crucial to better constrain the volcanic activity within the single evolutionary phases over time and their link to regional tectonics.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

An updated stratigraphy of Roccamonfina Volcano (Italy)

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The Roccamonfina volcanic complex (RVC), located in southern Italy, is a Middle to Upper Pleistocene stratovolcano that shares temporal and morphological traits with Somma–Vesuvius and Colli Albani volcanoes, both of which pose significant volcanic hazards to the cities of Naples and Rome, respectively. Therefore, understanding the RVC evolution may add essential features to refine the knowledge of its eruptive history and relationship with surrounding active systems. The RVC has been active between 630 and 55 ky, producing approximately 80 km^3 (DRE) of K-alkaline magma. The volcanic sequence alternates effusive and explosive episodes (with nested caldera formations) and more recent intra-caldera eruptions. Three main periods can be defined: i) the early formation and gravitational collapse of the stratovolcano; ii) the post-collapse and caldera forming period with two main caldera-forming phases which emplaced a succession of ignimbrites grouped in the Brown Leucitic Tuffs (BLT; 385-350 ky) and in the White Trachytic Tuffs (WTT; 322-305 ky); iii) a post-caldera period. This study, conducted in the frame of the CARG project for the geological mapping of Italy, provides preliminary results of a revised stratigraphy for the Roccamonfina volcanic sequence, highlighting new insights, especially in the pre-BLT stratigraphy. The collected data include new fieldwork observations and new geochemical and radiometric measurements obtained while preparing the two geological maps named Sessa Aurunca (sheet 416) and Teano (sheet 417).

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Revisiting the Holocene eruptive chronology of the Nevado Cayambe volcano, Ecuador

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Determining the eruptive chronology of the Northern Andean volcanoes is particularly challenging because their history of large eruptions separated by long periods of quiescence. Nevado Cayambe, a large ice-capped andesitic-dacitic volcanic centre in the Eastern Cordillera of the Ecuadorian Andes, exemplifies this complexity. Its eruptive chronology was initially outlined by Samaniego et al. (1998), who identified at least 23 eruptions during the last 4000 years. Holocene eruptive products at Nevado Cayambe include: (1) tephra fallout and surge deposits interlayered with organic-rich paleosoils, outcropped on the upper flanks of the volcano; and, (2) large pyroclastic density currents (PDC) deposits primarily exposed in the deep glacial valleys on the volcano's north-eastern flank. These deposits are associated with summit dome growth and subsequent collapses. Building on new field data, over 40 radiocarbon age determinations, and historical chronicles, we identified nine eruptive *episodes* since 4400 cal BP. A Bayesian approach, integrating radiometric and stratigraphic data, constrains the duration of each *episode* to 200-300 years, separated by quiescent intervals lasting several centuries. This refined chronology reveals correlations between tephra deposits and valley-ponded PDC deposits, suggesting that eruption magnitudes have increased over the past four millennia. Notably, the San Marcos *episode* (1280 - 1660 CE) produced significant valley-ponded PDC and surge deposits that impacted the upper north-western flank. Spanning the pre-Columbian and early colonial periods, this *episode* represents the most significant recent activity of Nevado Cayambe.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

GeoTeRi Database: A tool for exploring the geochemical evolution of post-caldera volcanism in Tenerife's central Teide-Pico Viejo Complex and Rift Systems.

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The active volcanic activity in the populated island of Tenerife (Canary Islands) primarily occurs in the central Teide-Pico Viejo (T-PV) complex and along the Santiago del Teide and Dorsal rift zones. Understanding the volcanic stratigraphy, petrology, and geochemistry of the central T-PV complex and its correlation with the rift systems is critical for improving hazard assessment on island. This study reviews the geochemistry of eruptive products from the last 180 ka, following the El Abrigo eruption, Tenerife's latest caldera-forming event. For this, we have constructed the GeoTeRi database, an extensive compilation of whole-rock major and trace elements analyses and isotopic data from over 43 published references. The current version of the database includes data from 561 rock samples, comprising over 500 whole-rock compositions and 172 isotopic analyses. Additionally, a review of the chronostratigraphy of the eruptions included in the database was conducted, drawing on published volcanostratigraphic maps and/or existing radiometric data, with the objective of giving a temporal context to the samples. A detailed statistical analysis of the database has been conducted to assess its robustness, evaluate the representativeness of the included samples, and identify key knowledge gaps in understanding the central T-PV complex. GeoTeRi aims to reconstruct the geochemical evolution of Tenerife's active volcanic system and serves as a foundation for future research. This research was partially funded by E.G., grant EVE (DG ECHO H2020 Ref. 826292) and the Intramural CSIC grant MAPCAN (Ref. 202130E083). OD was supported by an FPU grant (FPU18/02572).

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Exploring tephra records in the Azores peatlands

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Knowledge of a volcano's eruptive history is essential for volcanic hazard assessment and forecasting its future eruptive behaviour. The study of water-laden sedimentary archives revolutionised the reconstruction of past volcanic activity, as they usually hold a better-preserved tephra record than subaerial environments. Studies in the Azores revealed numerous tephra layers in lacustrine and marine sedimentary records, but the potential of peatlands as another, notionally better, sedimentary archive remains unexplored. Peatlands are ubiquitous in the Azores highlands due to their heavy rainfall conditions and cool, even temperatures. Critically, peatlands (many of which were former lakes) constitute ideal traps for preserving tephra layers, resulting in expectedly rich, easily dated (with radiocarbon) sedimentary records from which uniquely detailed volcanic activity reconstructions can be derived. To take advantage of the ubiquitous peatlands, we devised a multidisciplinary project that will tap this record, for the first time in the Azores, and explore its potential for the detailed reconstruction of the eruptive history of Pico Island, which is characterised by numerous basaltic monogenetic eruptions with small tephra dispersal footprints, thus requiring widespread and easily accessible sedimentary archives for an effective reconstruction of its past volcanic activity. We plan to undertake a prospective coring campaign on Pico's peatlands, followed by stratigraphic, geochemical, paleoenvironmental, and geochronological correlations of peat sequences to test their potential for detailed eruptive history reconstructions. This project will also offer insights into Holocene climate changes and the sensitivity of peatlands as major carbon sinks in the Azores. ExTRAP project funded by FCT ref. 2023.12382.PEX

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

CatVolc: A Comprehensive Database of Geochemical and Geochronological Data from the Catalan Volcanic Zone, Spain

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The Catalan Volcanic Zone (CVZ) in northeastern Spain is an intraplate alkaline volcanic region linked to the Western Mediterranean's opening and the European Rift System's development. Volcanic activity began in L'Empordà (>12–8 Ma), progressed to La Selva (7.9–1.7 Ma), and culminated in the Garrotxa Volcanic Field (<0.7–0.01 Ma). Despite decades of research, key aspects remain unclear, including magma plumbing systems' evolution, ascent mechanisms, and a detailed chronology of volcanism. Addressing these gaps requires consolidated geochemical, petrological, and geochronological data, which have remained scattered and unintegrated. This study introduces the CatVolc (Catalan Volcanism) database, unifying geochemical and geochronological data for volcanic materials in the CVZ. It includes analyses of 405 rock samples (296 juvenile magmatic rocks, 109 xenoliths) and radiometric/thermoluminescence ages from 57 rocks, 4 paleosols, and 1 sediment sample. Each entry provides information on sampling sites, lithology, whole-rock compositions, isotopic ratios, mineral chemistry, and/or radiometric/thermoluminescence dating. Preliminary analyses of CatVolc reveal critical knowledge gaps and suggest future research directions. This database is essential for understanding magmatic systems and volcanic activity within the CVZ, particularly the Garrotxa Volcanic Field, aiding hazard assessment and improving insights into future eruptions. This work has been developed under the financial support of the Institut Cartogràfic i Geològic de Catalunya, the Parc Natural de la Zona Volcànica de La Garrotxa, the Fundación General CSIC's ComFuturo programme and the Marie Skłodowska-Curie grant agreement No. 101034263, and the grants 2021 COLAB 00367 (MEFP), and PID2022-

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Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Eruptive History of the Garibaldi – Price Volcanic Field, British Columbia: Canada's Highest Threat Volcano

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The Garibaldi Volcanic Belt, spanning northern Washington and British Columbia (BC), represents the northern extent of the Cascades Volcanic Arc. This belt includes Nch'ḵay̓ / Mount Garibaldi, the most threatening volcano in Canada, a prominent feature of a multi-vent Quaternary volcanic field located 60 km north of Vancouver, BC, and active since 1.3 Ma. Building on foundational research from the 1950s and 1980s, new geological mapping, petrological data, and radiometric dating are used to interpret its eruptive history, refine its geochronology, and assess future volcanic hazards. This volcanic field has been significantly dissected by glaciation, deglaciation, and other erosive processes, leaving many areas inaccessible. Nevertheless, the stratigraphy and eruption sequence were successfully reconstructed with the aid of helicopter photogrammetry. This volcanic field is predominantly calc-alkaline andesitic and dacitic resulting from intermittent volcanism: from 1.3 to 1.0 Ma, andesitic eruptions formed the basal formations of The Black Tusk, Mount Price, and Brohm Ridge centres. Between 0.7 and 0.4 Ma, activity shifted southward, dominated by dacitic eruptions, extending the Brohm Ridge and Round Mountain complexes. From 0.4 to 0.02 Ma, volcanic activity became more widespread, characterized by intermediate to felsic eruptions constructing the major volcanic edifices. Post-glacial eruptions (14–10 ka) at Opal Cone, Clinker Peak, and Dalton Dome produced voluminous intermediate to felsic lava flows. Our refined mapping and geochronology results are used to assess future volcanic hazards. Using a scenario-based approach, we aim to provide information to support organizations and communities in evidence-based decision-making about the volcanic risks.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

New evidence for prolonged ash emission during silicic eruptions in Iceland

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There is increasing evidence that the apparently effusive phase of silicic eruptions may be hybrid in style - including sustained ash emissions alongside lava emplacement. However, the prevalence of hybrid activity in past events remains unknown and is little documented. Recently recognized features that are diagnostic of hybrid activity are veneers of welded ash found on lava fracture surfaces. We show that these veneers are present on all Holocene rhyolitic lavas of Torfajökull volcano, Iceland. We focus on lavas of the 877 CE Hrafntinnuhraun eruption and show that such ash veneers present in all of its flow units are texturally comparable to those described from Cordon Caulle, indicating that similar ash venting likely took place throughout the entire lava- producing phase of the Hrafntinnuhraun eruption. We construct a simple first-order model for the rates of ash capture by veneer surfaces and upscale this calculation to the whole eruption, allowing us to estimate the total ash mass that can be sequestered. We posit that such hybrid explosive-effusive activity is common to silicic volcanism in general and that it represents an insufficiently recognized hazard.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Post-caldera recovery of a peralkaline magmatic system: Tūhua, New Zealand

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Tūhua (Mayor Island) is an isolated peralkaline rhyolite volcano situated ~80 km behind the active calc-alkaline volcanism of the Taupo Volcanic Zone, New Zealand. The largest, most recent caldera-forming eruption occurred ~7.2 ka (the 'Tūhua eruption') with tephra reaching up to 300 km from source. This eruption was followed by overwhelmingly effusive activity generating a ~0.4 km^3 composite pile of intra-caldera lava lobes that bury ~80 % of the caldera floor. Current interest focuses on recent, post-caldera activity and the potential for future unrest or eruption. Here we consider the eruptive record of post-caldera activity to assess the young evolution of the magmatic system. Tūhua eruption products show wide geochemical variations (Zr = 1010-1369 ppm) and are relatively crystal poor (<5 %). In contrast, the younger lava lobes have a narrower compositional range, with elevated Zr (1454-1693 ppm) and higher crystal contents (25-35 %). In addition, there is a post-7.2 ka fall deposit found on the caldera floor that is missing from the lava domes. Pumice in this deposit is crystal poor (like 7.2 ka pumices) but has elevated Zr values (1665-1698 ppm) like the young lavas. This explosive phase may correlate with a ~3-4 ka tephra in a nearby marine core, while the youngest lava activity is constrained by a 2.2 ka charcoal spike in caldera floor peat deposits. The absence of significant geothermal activity and the high crystal content of the latest eruption products suggests that the magmatic system is currently moribund.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

The intrinsic connection between tectonics and volcanism in Sumatra, Indonesia: A preliminary assessment

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A long-standing debate in the geosciences centers on the interplay between volcanism and tectonics. Southeast Asia, one of the most tectonically and volcanically active regions on Earth, hosts numerous active and hazardous volcanoes, with 116 in Indonesia and 33 in the Philippines. These volcanoes account for over 15% of the global eruptions recorded during the Holocene (the last ~12,000 years). Despite the proximity of many of these volcanoes to major tectonic features, the potential links between them remain largely unexplored. This study aims to provide an exploratory assessment of this relationship, by starting to analyse the link between physical and geochemical parameters across varying spatial scales. This includes erupted edifice volumes, magma storage depths, geochemical proxies, vent densities, regional stress orientations and edifice location with respect to regional tectonic faults. We started our assessments by focusing on selected land-based stratovolcanoes from Sumatra because considered representative of the amount of explosive volcanism that occurred in the area, and because Sumatra hosts the Sumatran fault, which runs for about 1600 km from north to south of the island, therefore ideal for this type of investigation. Future research will also include calderas and volcanic fields, extending the study area to Java and the Philippines for more regional assessment, and comparing to other arc systems such as the Cascades. The analyses are underway and the volume calculations are being conducted through the recently published and revised MATLAB-based version of MORVOLC. We aim to assess our multidimensional geospatial datasets by leveraging machine-learning based statistical techniques.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Fighting fire with water: microstructural and geochemical imprint of explosive volcanism in coral skeletons

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Characterising the eruptive history of a volcano is essential for hazard assessment and mitigation. On tropical volcanic islands however, terrestrial deposits are often limited as large quantities of tephra are directly deposited into the surrounding seawater or subsequently remobilised during weathering processes. Volcanic tephra leaches multiple chemical elements on contact with water, which significantly impacts local and regional environments. Coral reefs growing around volcanic islands in the tropics thus experience periodic disruptions from explosive volcanism. These disruptions influence the seawater geochemistry and ecophysiology of the coral organism, resulting in microstructural and geochemical imprints within their aragonitic skeletal archives. We sampled coral cores along the north-west coast of St. Vincent in July 2024, three years after the April 2021 eruption of La Soufrière. Element/Ca ratios were measured using LA-ICP-MS analyses and microstructural porosity investigated by micro-CT scanning. Our results show elevated Mn/Ca concentrations at the time of the eruption coinciding with elevated skeletal porosity. Mn is leached rapidly from tephra when deposited in seawater and is an important micronutrient used in photosynthesis and subsequently skeletal growth. The skeletal concentration of REE's elements such as Y, La and Nd are also elevated after the eruption and exhibit clearer seasonality decreasing in amplitude with each year after the eruption. We interpret this prolonged signal as an indication of continued tephra leaching from lahars and weathering during the rainy season. These results highlight the utility of massive corals in reconstructing past explosive volcanism, but challenges distinguishing primary tephra deposition from remobilisation due to lahars.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

A late Pleistocene-Holocene record of explosive eruptions from central Sumatra (Indonesia) in the western Sunda Volcanic Arc

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Explosive eruptions in Sumatra, Indonesia with VEI 3-5 have received inadequate attention due to their limited preservation in the proximal record. This knowledge gap hinders existing attempts to conduct hazard assessments for these potentially impactful eruptions. Here, we address this disparity by presenting geochemical, geochronological and tephrochronological datasets associated with tephra sampled from deep-sea cores collected off the western Sumatran coast, as well as pyroclastic deposits throughout central Sumatra. Our datasets reveal correlations between seven tephra layers and their proximal sources and provide new constraints on the eruption ages, volumes and sizes. Notably, we identified three VEI 5 eruptions, including the ~1.53 ka Lubuk King Tephra eruption from Malintang (≥1.4 km^3 DRE of magma), which represents the youngest known VEI 5 eruption in Sumatra and the two temporally proximate (~580 yr apart) Tandikat II and I Tephra eruptions (≥1.1 and ≥2.7 km^3 DRE of magma) at Tandikat around ~4.36 and ~4.94 ka, respectively. We ascertained that at least two VEI 4 eruptions occurring within the last 36 kyr are correlated to the currently active Marapi. We also traced two tephra layers (AB4 and AB5; ~36.8 and ~41.0 ka) to VEI ≥ 5 eruptions at two eruptive centres in neighbouring provinces (Ranau Tuff from South Sumatra and Djudjun Tephra from Jambi). Source provenances for another six tephra layers remain unknown due to the lack of proximal correlatives. This study provides an improved tephrochronological framework for late Pleistocene-Holocene explosive volcanism in Sumatra that will help improve volcanic hazards assessments for the region.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Reconstructing the volcanic history of Ulukışla Caldera to improve the hazard assessment around the Hasandağ Volcanic Complex (Central Anatolia)

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The Ulukışla Caldera (a structure of 2.5 km x 4 km) is part of the Hasandağ Volcanic Complex (Central Anatolia, Turkey) and has been only recently identified as a collapse structure surrounded by several undifferentiated pyroclastic deposits until this study. This study presents a tephrostratigraphic analysis to reconstruct the origin and volcanic evolution of Ulukışla Caldera, examining its volcano-tectonic relationship with the Tuz Gölü Fault Zone (TGFZ). To achieve this, we integrated detailed volcano-stratigraphy, deposit descriptions and distribution, glass chemistry, geochronology, and remote sensing. We identified three major eruption deposits: 1) the ~442 ka pre-caldera Yenipınar Ignimbrite, 2) the ~400 ka Belbaşhanı caldera-forming ignimbrite, and 3) the ~326 ka post-caldera Ulukışla Fall. Since the Ulukışla Caldera is emplaced within (semi-) grabens of the TGFZ, synthetic and antithetic faults have facilitated the formation of the strike-slip/graben caldera. This active fault system may also control the volcanic activity across the entire Hasandağ compound volcano. Recognising this potential volcanic-tectonic relationship is essential for understanding future eruptive behaviour of such volcanic system. Given the Hasandağ's location within this complex tectonic setting, the possibility of a new cone gravitational collapse (e.g., Greater and Lesser Hasandağ) and/or the formation of additional volcanic collapse structures should be included in future volcanic/tectonic hazard assessments. This study has been funded by the PÜSKÜRÜM project (a Marie Skłodowska-Curie Action (grant #101024337) under the European Union's Horizon 2020 research and innovation programme) and the TURVO project (PID2023-147255NB-I00), supported by MICIU/AEI/10.13039/50110001103.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Long-lasting, small-to-moderate eruptions at composite volcanoes: the largest eruption of Mt. Ruapehu (Aotearoa New Zealand) in the last 1800 years

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Small-to-moderate explosive eruptions involve tephra volumes ≤0.1 km^3 and VEIs≤3. The ejected material often comprises significant amounts of ash-sized pyroclastic material, reducing the preservation potential of associated deposits and leading to the underrepresentation of these eruptions in long-term, frequency-magnitude datasets. Mt. Ruapehu has produced at least 32 small-scale eruptions over the past 1800 years, with the largest of these eruptions lasting several months to years and depositing the widespread T13-sequence. The cumulative deposit volume of 0.15 km^3 is an order of magnitude larger than average deposit volumes of the past 1800 years. The T13-ash-lapilli-sequence comprises six depositional units with variable tephra dispersal, deposit texture and pyroclast characteristics. These represent at least five explosive phases of variable intensity and magnitude: the initial phase shows a dispersal limited to 11 km and a tephra volume of 8.5×10^5 m^3, while the following peak phase comprises a widely dispersed unit with a volume estimated at 8.8×10^7 m^3. Combination of deposit characteristics with the textural analysis of different types of juvenile clasts suggests that shallow processes in the conduit, such as degassing and crystallisation are the main factors controlling eruption style and intensity. The multilobate and irregular tephra dispersal, together with laterally variable pyroclast assemblage, indicate unsteady and wind-controlled eruption plumes. This study allows to discuss the complexity of tephra sequences associated with long-lasting, small-to-moderate eruptions, as well as their key eruption parameters that can be obtained through detailed deposit characterisation and the main limitations associated with existing classification schemes.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

New chronological and petrological constrains of the caldera-forming eruption of Cuicocha volcano (Ecuador)

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Studying past eruptions of potentially active volcanoes gives insight into future eruptions magnitude and potential hazards. Cuicocha is a relatively young and potentially active volcanic center located in the Northern Andes of Ecuador. It is situated near densely populated areas, including Cotacachi and Quiroga (40,000 inhabitants). Previous studies described a large explosive eruption (VEI 5; 3.1 – 2.9 ka) that destroyed an older dome complex, forming the current caldera. Our new geochronological data refine the eruptive chronology, including at least one eruption between 3890 ± 30 and 4495 ± 30 years BP (uncalibrated ages). In addition, the current Cuicocha lake fills a funnel-shaped depression (3 km diameter) associated with the large caldera-forming eruption dated between 2480 ± 30 and 2980 ± 30 years BP. The eruptive products of this eruption include large pyroclastic density currents (flow and surges), and tephra fallout deposits. The last eruptive products of this volcanic center correspond to three intra-caldera lava domes, which sealed the activity. Eruptive products display a homogeneous andesitic composition (61 – 63 wt.% SiO_2), with phenocrysts of high-alumina amphibole, plagioclase (An_{39-78}), and magnetite. Thermo-barometry and melt inclusions study suggest that the caldera-forming eruption was fed by a magma reservoir in equilibrium at 400-600 MPa (i.e. 14-20 km depth), 830 ± 20°C and at least 4 wt.% H_2O. The presence of mafic enclaves and the reverse and oscillatory zoning patterns in plagioclase phenocrysts suggest that the triggering mechanism was the recharge of deeper mafic magma into a crystal-rich reservoir.

Theme: 3. Volcanic processes

Session 3.4: Unravelling eruptive histories of volcanoes to understand future behaviour

Allocated presentation: Poster

Spatio-temporal distribution and evolution of the distributed volcanism, central Mexico: examples: Valle de Bravo, Chichinautzin and Michoacán-Guanajuato volcanic fields.

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From the analysis of volcanoes in the volcanic fields of Valle de Bravo (VBVF), Sierra Chichinautzin (SCVF) and Michoacán-Guanajuato (MGVF) in central Mexico, we identify spatial and temporal distribution patterns of past eruptions. These three volcanic fields are located in the central part of the Trans Mexican Volcanic Belt (TMVB), result of the subduction of the Cocos and Rivera plates beneath the North American plate since the Miocene. All these volcanic fields are limited by polygenetic volcanoes such as Popocatépetl to the East, Nevado de Toluca in the middle and Colima volcano to the West. In the VBVF we can find scoria cones, domes, dome complexes and one small shield volcano. The SCVF includes scoria cones with lava flows, shield volcanoes crowned with a scoria cone and coneless lava flows. The MGVF includes lava domes, scoria and cinder cones, small-to-medium-shield volcanoes, maar volcanoes, fissure-fed lava flows, and a few stratovolcanoes. The total number of vents in VBVF is 143 in an area of 3,700 km^2 vents/km^2, with an average density of 0.0386. SCVF is 227 in an area of 3,500 km^2, with an average density of 0.064 vents/km^2. In the MGVF there are 1,148 volcanoes in an area of 26,200 km^2, which represents an average density of 0.043 vents/km^2. Main orientation of vents in VBVF is 30°-40° (NE), in SCVF is mainly east-west, from 70° to 115° and in the MGVF are 20°-100° (N-E) and 90°-120° (N-SE). In these areas it is necessary to carry out a volcanic risk assessment.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk [Invited]

15 years of lahar monitoring at Volcán de Colima, Mexico: insights on triggering mechanisms, flow characteristics and hazards assessment.

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The Volcán de Colima, Mexico, is a natural laboratory for studying lahars, including their initiation mechanisms, downflow behavior, and associated hazards. A comprehensive monitoring system incorporating seismic, visual, and rainfall data was established in 2010 and now covers lahar detection along four ravines. Morphology surveys using drones have also been implemented. Real-time monitoring at Volcán de Colima has enabled the seismic classification of lahars based on their magnitude and sediment concentration, characteristics linked to the watershed morphology of each ravine and the rainfall intensity-duration. On the upper volcano slopes, progressive sediment entrainment promotes the transition from hyperconcentrated flows to debris flows, characterized by the succession of surges with block-rich fronts. In the middle and distal reaches, the channel morphology highly controls bulking and debulking processes, responsible for lahar downflow variation in magnitude and sediment concentration. The 2015 eruption deposited over 7 million cubic meters of pyroclastic material into the Montegrande ravine which, since then, recorded up to 40 lahars per year during the rainy season. Based on morphological survey, an erosion rate of up to 10^5 cubic meters per year has been estimated. In contrast, along other ravines, unaffected by pyroclastic deposition during the last 20 years, lahars are generated only during exceptional rainfall events, with sediments primarily sourced from material accumulated at the foot of the terrace wall due to minor landslides. These findings have advanced lahar detection and hazard assessment at Volcán de Colima, enhancing understanding of sediment dynamics and flow behavior.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk [Invited]

From volcanic sink to source: Unravelling eruption records from volcanic wet mass flow deposits in fluvial and lacustrine successions

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Geological records of primary tephra fall and pyroclastic density current deposits are often incomplete due to post-depositional degradation of primary deposits and low preservation potential at high relief volcanic slopes proximal to the eruption source. These effects are especially pronounced with small-scale eruptions. This study evaluates the past volcanic activity at Adatara and Banda volcanoes (Japan) by describing and analysing volcanic wet mass flow deposits in fluvial and lacustrine successions (Kataoka and Nagahashi, 2019; Kataoka, 2023). In detail, we study eruption-associated lahar deposits and runout deposits from upstream to downstream by: 1) surveying outcrops along rivers, 2) drilling cores from fluvial terraces, alluvial and delta plains, and 3) collecting piston cores from Lake Inawashiro—the terminus of the river basins. We identify terrestrial lahar deposits associated with small-scale phreatic eruptions at Adatara and correlate these with sub-lacustrine density current deposits. In addition, we find sub-lacustrine density current deposits in the lake core sediments associated with large-scale edifice collapses at Bandai. We characterise these event deposits in terms of sedimentary facies, mineral composition, whole-rock chemistry, clay content, alteration (clay) mineral composition, and volcanic glass-shard composition. The ^{14}C ages from lahar deposits and the depositional ages of the lacustrine deposits constrain timing of these events and provide a more detailed chronology of volcanic eruptions at the two volcanoes. The observation that some event deposits do not correspond to previously reported tephra and lahar deposits is indicative of multiple unknown eruptions and implies a higher frequency of eruption-associated lahar events than previously assumed.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Lahar sedimentology and spectral fingerprinting: A reassessment of Mount Ruapehu's Onetapu Formation

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Lahars pose significant hazards to communities surrounding active volcanoes, potentially impacting areas over 100 km from their source. The ability to 'fingerprint' and correlate lahar deposits across different catchments is crucial for understanding their triggers and flow behaviour. This study integrates spectral, XRD, and sedimentological analyses to develop diagnostic signatures for a sequence/series of Late Quaternary lahar deposits in two catchments on Mount Ruapehu, New Zealand. Our research questions focus on distinguishing between collapse-triggered and hydraulically reworked deposits and correlating distinct fingerprints between units. Field mapping documented stratigraphic relationships and sedimentological characteristics for 17 members of the Onetapu Formation across five assemblages. Spectral angle mapping of 108 bulk sediment samples, analysed using Visible-Shortwave infrared (350-2500 nm) reflected light spectroscopy, revealed distinct spectral clusters between units and varying proportions of kaolin and smectite group minerals derived from hydrothermally altered source rocks. This enabled correlation of deposits between catchments and identification of previously undocumented flow paths, as well as distinguishing debris-flow and hyperconcentrated-flow deposits where high clay contents suggest a landslide origin. Results show that at least two debris flows travelled down a previously unmapped catchment and contributed to two of the five main Onetapu Formation assemblages, including deposits comprised of remobilised Taupo ignimbrite rhyolitic material (~1850 yr BP). This fingerprinting approach enhances our ability to trace lahar deposits across complex terrain and provides new insights into the tempospatial distribution of lahars in this active volcanic system, while also improving our understanding of their trigger mechanisms and potential hazard impacts.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Volcano-sedimentary interactions in a Plio-Pleistocene intra-arc basin of the Patagonian Andes: fluvial responses to explosive and effusive eruptions

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Understanding how volcanic eruptions influence the dynamics of a sedimentary system is challenging and has motivated extensive research. These processes remain incompletely understood, emphasizing the need for integrative interdisciplinary studies. Volcano-sedimentary systems exhibit unique characteristics, influenced by factors such as the type and volume of the volcanic activity (explosive vs. effusive), sedimentary system attributes, and geotectonic settings (e.g., transtensional, extensional, compressional regimes). This study presents preliminary findings from the Plio-Pleistocene Hualcupen succession, located in the intra-arc region of the Southern Volcanic Zone of the Andes, Argentina. Two distinct fluvial responses to explosive and effusive eruptions were identified and compared: (a) explosive eruptions associated with a scoria cone generation led to increased sediment supply, resulting in widened, shallower channels with sheet-like flows following substantial pyroclastic input; (b) effusive lava flows filled and leveled pre-existing channels, triggering channel avulsion, subsequent periods of fluvial incision, and the development of deeply incised channels. Both volcanic events induced local base-level modifications and changes in the accommodation/supply ratio, compelling the fluvial network to reorganize. We propose a conceptual model delineating the primary hydromorphic responses to effusive and explosive eruptions, which may provide insights for intra-arc basins within the Andes and comparable systems worldwide.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Simulation of the 2012 Te Maari debris avalanche: insight into the failure mechanics and the role of the hydrothermal system.

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The generation of volcanic mass flows is driven by various initiation processes that result from a combination of preparatory and triggering factors. These initiation conditions largely affect flow dynamics including landslide mobility and runout distance, which pose significant risks to nearby populations and infrastructures. Tongariro, an active andesite volcano, experienced one of New Zealand's most recent debris avalanches at the Upper Te Maari crater on August 6, 2012. This debris avalanche released a volume of 7×10^5 m^3 of material from the source, which by unloading the pressurised vapour-dominated hydrothermal system, led to a phreatic eruption. We use finite-element modelling to identify causes of the Te Maari slope failure, and assess the sensitivity to varying groundwater, seismic and mechanical conditions. Model results closely match the observed failure when considering the strength of hydrothermally altered rocks subjected to an increased pore pressure at shallow depth. We found that even a relatively minor rise in pore pressure, ≈ 200 kPa in the upper layers, could replicate the observed failure at Te Maari. Our simulations also reveal that this debris avalanche might be a multiple-stage failure involving the progressive sliding of two distinct blocks. These findings better constrain preparatory and triggering factors that affect avalanche flow and emplacement, improve our understanding of Tongariro's mass flow deposits and enhance hazard assessments for future potential collapses at Tongariro and other volcanoes with hydrothermal systems.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Erosion dynamics and morphological evolution of composite volcanoes: Insights from analogue modelling

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Volcanic landscapes, characterized by rapid growth and extended repose, serve as valuable natural laboratories for studying erosion patterns and rates across timescales. However, the complex morphologies resulting from concurrent erosional and depositional activities complicate the analysis of individual erosional processes in nature. Analogue models with rainfall-induced runoff provide a simplified, controlled setting to explore fluvial erosion, with well-constrained initial volcano cone size, slope, and complexity. This study uses analogue modelling to offer new insights into real-world volcanic landscape evolution. Experiments were conducted at the Vrije Universiteit Brussel volcanology laboratory using a custom-made rainfall-simulator. Cones made of a wet mixture of 70 µm silica powder were constructed on a drainage layer and the height, width and slopes were scaled from pristine natural composite volcanoes. The erosional and depositional evolution was documented at regular intervals using photogrammetry-derived DEM with sub-millimetre resolution. The influence of different initial flank slopes, the addition of a summit crater, erosion rate, and drainage basin forming were analyzed through geometric and drainage-based parameters. Results mimic erosion processes observed on natural volcanoes, where drainage basins widen and merge, decreasing drainage density over time. The presence of a crater accelerates initial summit erosion and drainage network maturity, creating wider basins. The steep upper slopes generate narrower gullies on the upper flanks, leading to a more rapid decrease in height. These various erosional processes, reflected in morphometric values, ultimately converge to a similar end state: equifinality represents a challenge for inferring the original shape of composite volcanoes from their degraded remnants.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Unexpected offshore hazards and sediment fluxes resulting from ocean-entering lahars

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Lahars are fast-moving flows of volcanic sediment mixed with water, representing some of the deadliest volcanic hazards and largest volume sediment flows of any type on Earth. Long runouts (up to 100 kms) and proximity of many volcanic centres to coastlines mean that lahars regularly reach the ocean, coincident with, and up to years after explosive volcanic eruptions. While many studies have characterised the behaviour and impacts of lahars on land, an absence of offshore observations means we lack an understanding of what happens when lahars enter the ocean. The existing (conceptual) model assumes a sediment-laden flow immediately and directly plunges beneath the sea surface as a hyperpycnal flow where it reaches the coast. New observations of ocean-entering lahars following the 2020/21 eruption of La Soufriere, St Vincent challenge this model, revealing more complex behaviour and hazards. Following the 2021 eruption, seafloor sediment flows destroyed five important fisheries and carried boulders and fresh vegetation tens of kilometres offshore, damaging >50 km length of subsea telecommunications cables. Lahars frequently and concurrently entered the ocean along multiple catchments forming buoyant surface plumes. The nature of offshore sediment delivery is often staged in time, wherein progradational deltas develop at river outflows that subsequently collapse into the ocean days to weeks later. Drawing on these observations we propose a new process-based model for ocean-entering lahars and discuss the implications for critical offshore infrastructure, fisheries, and fluxes of volcanic ash that play an important role in biogeochemical cycling at this and other coastal volcanoes worldwide.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Hyaloclastic beds in ancient submarine successions: insights from Italy and South Korea

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Water/lava interactions represent the fundamental mechanism triggering the emplacement of primary volcaniclastic layers in many non-explosive volcanic contexts. Nevertheless, rates of accumulation of such layers during effusive eruptions may be consequence of effusive rate variations. Under this light, this work explores the macro- and microscopic features characterizing two volcano-sedimentary successions exposed, respectively, in Southern Italy (Aci Castello Formation – Etna volcano) and South Korea (Dodong Basalts – Ulleung Island), accumulated by the outflow of basaltic melts during the first stage of construction of the Etna and Ulleung volcanoes. Combining fieldwork, petrographic and paleomagnetic analyses, the work proposes to explore mechanisms on the basis of generation and transportation of hyaloclastic particles in submarine contexts. In Aci Castello, basaltic effusion triggered the accumulation of pillow basalts, whereas primary volcaniclastic deposits consist of almost subvertical hyaloclastic layers with basaltic fragments and muddy rip-up clasts in a reddish groundmass. The succession is packaged in a prograding fan-like body. In turn, Dodong Basalts were accumulated as sheet-like basalts all around the basal part of Ulleung Island and are locally interbedded by primary volcaniclastic deposits. Such deposits are composed of fine to coarse grained yellowish particles and loose, cm-long pyroxene crystals. In both cases, macro- and microscopical observations are crucial in the identification of mechanisms at the base of hyaloclastic particles' rate of generation. This work was supported in part by the Italian Ministry of Foreign Affairs and International Cooperation, grant number KR23GR08.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Explosive volcanic activity recorded in a Pleistocene hot spring system: an example from central Italy.

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Explosive volcanic activity has played a pivotal role in shaping Earth's geological history, leaving distinct imprints in the rock record. During such events, magma ascent and eruption produce vast quantities of particles that are either ejected into the atmosphere or transported through surface processes into surrounding environments. As these represent relative short-lived events, identifying primary volcaniclastic deposits is critical for reconstructing detailed volcanic history and assessing its impact on the adjacent environments. However, these deposits may exhibit a low preservation potential, complicating their identification and differentiation from other volcaniclastic units. A major challenge in fossil deposits is distinguishing primary volcanic products from secondary materials formed by the weathering of antecedent materials. This issue is complicated when pyroclastic deposits, both air-fall and flow, interact with water in continental and marine environments, leading to potential misidentification or omission in the geological record. While primary pyroclastic deposits have been extensively studied in marine and lacustrine environments, terrestrial hot spring systems remain underexplored as records of explosive volcanic activity. This study investigates primary volcaniclastic deposits (from PDC and fallout events) within a fossil hot spring system in Southern Tuscany, Central Italy, offering the first comprehensive overview of their accumulation, alteration processes, and preservation potential in such environments. Petrographic analysis and high-resolution electron microscopy revealed significant post-depositional alteration of pyroclastic features and secondary (bio)minerals formation. These findings highlight the potential of hot spring systems to preserve volcanic records, enhancing our understanding of eruptive histories and regional geological evolution.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Resolving transient dynamics of erosion, deposition and sediment transport in lahars and debris flows using field observations and LaharFlow model simulations

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Lahars and debris flows are hazardous, concentrated, gravity-driven flows of mixtures of water, rock, and other debris entrained along their flow paths. Changes to their transported solids content through morphodynamic processes of erosion and deposition controls their rheology and basal friction, and ultimately their flow dynamics and impacts. In this study we test the capability of LaharFlow (a pragmatic dynamic shallow-layer model for lahar hazard assessment) to reproduce complex patterns of erosion and deposition preserved in a debris flow deposit, and use the model to explore the transient dynamics of sediment transport in concentrated flows. Field observations from the July 2015 Cancia debris flow (Italy) were used to identify elevation changes due to erosion and deposition over 20 m lengths along its deposit, and calibration of erosion and deposition parameters of the LaharFlow model was able to reproduce this pattern to high fidelity. Time-dependent model outputs showed that rates of erosion, deposition and flow mass flux varied along the channel during the lifetime of the flow, but the flow was consistently erosive on slopes greater than 25^{o} and predominantly depositional on slopes less than 15^{o}. Distinct pulses of high sediment concentration propagated downstream at approximately constant rates that were comparable to the front speed. Simulations using LaharFlow at Volcan de Fuego (Guatemala) show longitudinal profiles of sediment concentration through the flow that are consistent with previous field interpretations. Comparisons with simulations without morphodynamic processes included highlight their essential role in flow dynamics, and thus hazard and impact assessment.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Talk

Ice-magma interactions in a shallow subglacial fissure eruption at Northern Laki (1783 CE); deposition and post-eruptive evolution in a dynamic environment.

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Substantial parts of Iceland's active volcanic zones are presently ice-covered, and fissure eruptions beneath glaciers are common. It has been hypothesised that fissure eruptions at or within ice-marginal settings would be predominantly phreatomagmatic and generate jökulhlaups. However, globally, few historical examples have been directly observed. Analysis of rare landforms like these is important for interpreting paleo ice-extents and understanding how they are preserved in this dynamic erosive environment. The final phase of the 1783–84 CE Laki flood basalt event in the Síða highlands of South Iceland was characterised by fissure propagation under Síðujökull, an outlet glacier from the Vatnajökull ice-cap. Dry, magmatic eruptive activity transitioned laterally to a phreatomagmatic eruption. 2.5 km-long shallow sub-glacially erupted formations offer anatural laboratory to understand the dynamics of fissure eruptions in a shallow subglacial or intraglacial setting from a rare known historical example. Field mapping and drone photogrammetry reveal a sequence dominated by phreatomagmatic tuff deposits intercalated with hackly jointed lobate lava flows, hackly jointed intrusions, and debris flows capped by spatter fed lavas suggestive of fluctuating water levels. The morphology of the formation displays increasing degrees of lateral confinement by the glacier towards to NE. A thin layer of glacial till caps the top of the formation indicating Síðujökull re-advanced over the area after the eruption. The glacier has since receded, removing lateral support from the fragile formation and triggering multiple landslides., Historic photogrammetry datasets show past glacial surges (*1964-1994 CE),* which may have contributed to weakening and failure.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

The offshore imprint of the 2008 eruption of Chaitén, Chile

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The 2008 explosive eruption of Chaitén volcano (Chile) dispersed tephra across the surrounding region, forming a widespread fall deposit extending eastward across Argentina. Rainfall remobilised proximal fall deposits in the days following the eruption, rapidly funnelling material through two local drainage basins and forming lahars with terrestrial pathways of 10-15 km. The southward directed lahars inundated Chaitén town and extended the coastline through rapid accumulation of volcaniclastic sediment. A major proportion of erupted products entered the ocean via post-eruptive laharic processes, but the ultimate fate, impact and distribution of this material is unknown. Here, we report preliminary results of marine research expedition FKt240902 (Schmidt Ocean Institute; September 2024) that surveyed the region offshore Chaitén. This project investigated the impacts of the Chaitén eruption in the marine environment (and subsequent recovery), the processes dispersing volcaniclastic sediment that entered the ocean, and the potential of historic secondary volcaniclastic stratigraphies in southern Chile. The FKt240902 expedition collected extensive bathymetry and sub-bottom profiles throughout the seas west of Chaitén, providing the first high-resolution mapping of the region. Oceanographic measurements, alongside these geophysical data, demonstrate a complex glacially sculpted seafloor and current dominated regimes, strongly influencing marine tephra deposition. Remotely-operated vehicle observations and sediment cores identified deposits from Chaiten extending at least 20 km offshore, including deposits likely originating from the 2008 eruption, alongside earlier events. Initial results demonstrate strong potential for offshore records to provide high-resolution eruption

histories, and a route to exploring the interaction of volcanic, climatic and environmental change in the region.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Block analysis from lava dome collapse deposits

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Lava domes are an unstable accumulation of viscous lava at an active volcanic vent. Dome collapses can generate block-and-ash flows (BAFs), which are typically small volume (<0.5 km^3) and contain a proportion of dense, juvenile blocks derived from the source dome, and a fines fraction comprising ash generated by attrition and abrasion of the juvenile material. Volcán de Colima is a stratovolcano in the western portion of the trans-Mexican volcanic belt which undergoes frequent periods of dome growth and destruction. The collapse of the recent lava dome on the 10th and 11th July 2015 produced two BAFs that deposited along the Montegrande and San Antonio barrancas. With runout distances of 10.7 km along the Montegrande barranca and 6.5 km along the San Antonio barranca; and a total estimated volume of 4.5×10^6 m^3. During this eruption, blocks originated from the collapse of the freshly emplaced lava dome as well as the crater rim. Grain size analysis is typically limited to particles <64 mm in diameter, even though blocks of several metres in size can be found throughout the deposits. We sampled both fine material and blocks at 1 km intervals along the Montegrande barranca. By combining characterisation of the sampled materials with drone surveys and image analysis, we present here a robust particle size distribution particularly focused on characterising blocks within the flow. We use these new data to infer conditions in the lava dome prior to collapse, current conditions, and transport capacity.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Measurement protocol proposal for the rheological characterization of volcanic sediment suspensions

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The study of the rheological behavior of water-sediments suspensions is fundamental for understanding the fluid-dynamic behavior of geophysical gravity flows. Lahars represent the volcanic case of such flows; they occur along the slopes of volcanoes and consist of large blocks of sediment supported within a matrix of fine sediment suspended in water. Most of the stresses are distributed within the fine matrix, i.e., the water-fine sediments suspension, due to its abundance in the flow and its capacity to support the large blocks. These stresses are mainly generated by the deformation naturally imposed by the slope of the volcano, while the matrix material presents a resistance to this deformation, which can be described by rheological models. In this study, we focused on the rheological characterization of the matrix using a small-scale concentric cylinder rheometer.Specifically, this work proposes an appropriate measurement protocol for the rheological characterization of fine sediment homogeneous suspensions that achieved the necessary physical conditions to establish a laminar and steady flow and without slippage phenomena. The proposed protocol consisted of a staircase function testing a shear-rate range between to with a homogenization step between each measurement step.Different measurement times were tested according to the maximum sediment settling time in a virtual column of homogeneous particle suspension. The settling time was calculated by estimating the settling velocity of the particles within the suspension.First results obtained from the use of this protocol show that the apparent viscosity depends on the shear rate, with an inverse exponential relationship with increasing shear rate.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

The application of high resolution (2m) EarthDEM and ArcticDEM digital elevation models to detect and quantify volcanic activity: successes and challenges

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Quantifying topographic changes in volcanoes provides important information about volcanic activity, which can also be used in forecasting future volcanic hazards. EarthDEM and ArcticDEM are Digital Elevation Models (DEMs) derived from Maxar satellites stereo-optical data. These DEMs allow for potential global volcanic monitoring of topography at a high resolution (2m) but have not frequently been used to study volcanoes so far. We used these DEMs to detect and quantify volcanic activity, as well as to show the successes and challenges of using this data. We studied >10 volcanoes, ranging from equatorial to polar environments placed in Indonesia; Galápagos (Ecuador); Kamchatka (Russia); Alaska and Aleutian (USA). These volcanoes experienced different volcanic eruptions that generated a wide range of volcanic deposits (lava flows and domes, pyroclastic density currents, lahars) and mass-wasting or erosional features. The high resolution of these DEMs allowed us to detect many topographic changes not visible with lower resolution DEMs, also in difficult environmental conditions (e.g. snow covers). Cloudless, artifact-free DEM data were most successful for quantifying height changes and volumes, also in small and narrow regions (e.g. channels). The only limit to detect height changes is when they are in the range of vertical data errors (1-2m). Our results demonstrate the value of EarthDEM and ArcticDEM in detecting and quantifying unique signals related to volcanic activity in different environments. If these high resolution DEMs become more frequently acquired in space and time, they could significantly improve our ability to develop time-series of volcano topographic changes worldwide.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Analysis of the 4 December 2021 lahar on Mount Semeru using remote sensing data.

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Mount Semeru in Indonesia is a prolific producers of lahars, driven by its ongoing volcanic activity and humid tropical climate. On December 4, 2021, an eruption triggered a dome collapse event. The combination of heavy precipitation and the remobilization of volcanic block-and-ash flow material resulted in the formation of a deadly lahar causing 51 fatalities and significant economic and agricultural damage in the southeastern portion of the ring plain. The combined application of radar and optical remote sensing allowed for an analysis of the laharic processes and resulting geomorphic change which provides invaluable information for improving modelling and hazard mitigation. Radar remote sensing enables the study of these processes in tropical environments where cloud coverage impedes optical and ground observations. This study combines observations from Sentinel-1 amplitude images and derived products with high resolution Planet surface reflectance images for calibration of interpretations. In parallel to amplitude images, rain fall accumulation data was integrated to focus on the triggering mechanisms of the lahar which would support future decision making and mitigate human losses.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Unravelling an arc-derived Miocene explosive eruptive record preserved in the North Patagonian Andean retro-arc

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Explosive volcanic eruptions deliver diverse tephra to the background sedimentary systems triggering environmental effects along a time span ranging from hours to millennia. Advances in understanding volcaniclastic processes have occurred from different scientific perspectives related to direct observations of volcanic eruptions and the analysis of ancient volcanic successions. As a result, volcaniclastic stratigraphy dealt with short- to long-term (hs to Kyrs) overlapping volcanic signals resulting from different eruptive parameters (composition, magnitude, and frequency) and syn- to post- and inter-eruptive Earth System responses. Through volcanological and sedimentological architectural and facies analysis of a Miocene explosive eruptive record preserved in the North Patagonian retro-arc, we develop a high-resolution stratigraphic scheme that hierarchizes short- to long-term arc-derived volcaniclastic processes and reveals different volcanic signals of one of the most relevant episodes of the Patagonian Andean Arc history. The volcaniclastic assemblage allows us to interpret two depositional volcaniclastic alluvial systems related to syn- and inter-eruptive periods (yrs to Kyrs) of an arc-derived explosive eruptive epoch (Ma to Ky) that occurred within the North Patagonian Andes in Miocene times. Pyroclastic units represent short-term explosive volcanic signals related to arc-derived explosive volcanic eruptions with different magnitudes and frequencies. Secondary volcaniclastic units of syn- to post- and inter-eruptive deposits of the volcaniclastic alluvial succession reflect short- to long-term environmental effects modulated by climate and tectonic topography.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Dynamics of Magmatic Processes and Subsurface Structures Unveiled: A Geophysical Study in the Hainan volcanic field

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The Hainan volcanic field (HNVF) is one of China's most active Holocene volcanic areas. Due to a lack of comprehensive geophysical research, questions persist regarding the deep magma system structure of the HNVF. For example, it is unclear whether the intense seismic activity in its eastern part may be a precursor to renewed volcanic activity. We present new three-dimensional electrical conductivity images, derived from magnetotelluric data, that provide a new understanding of the deep magma system in the HNVF. Our results reveal the presence of multiple sets of low-resistivity structures in both shallow (<5 km) and deep (5~25 km) regions. Although once associated with past volcanic activity, a widespread shallow low-resistivity layer on the northwest side of the HNVF is not currently indicative of shallow magma chambers. Instead, a large-volume low-resistivity structures in the western part of the HNVF may represent the current crustal magmatic plumbing system. Our analysis suggests that the intense seismic activity in localized areas of the crust lacks corresponding low-resistivity structures, which indicates that there is no direct correlation between seismicity and movement of magma. Recent volcanic eruptions in the HNVF are primarily concentrated near the Changliu-Xiangou fault, which may indicate that the migration of magma in the HNVF has utilized crustal weak zones.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

How the size of scoria cones controls morphological response to erosive processes: insights from numerical models.

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The morphometric evolution of scoria cones provides an alternative for assigning relative ages to these features within volcanic fields, where not all have been radiometrically dated. Several studies have highlighted the influence of different erosive conditions on the morphological response of individual scoria cones to erosive processes (e.g., lithology, climate, vegetation cover, etc.). Recent research suggests that a cone's size also impacts the evolution of its morphometry under specific erosive conditions, such that its basal area is a decisive factor in sustaining or dampening incision by rills and gullies on the volcanic edifice. Understanding how different processes and factors interact to shape volcano morphologies under erosive processes over the landform's lifespan is needed to constrain morphometry-based dating methods of scoria cones further and contribute to improving the hazards assessment of volcanic fields. To gain further insight into the influence of cone size on the morphological evolution, we use a simplified landscape evolution model, assuming that the different erosive processes can be expressed as a competition between advection and diffusion. We use a non-dimensional representation of non-linear transport laws (stream power law and soil diffusion) to test different scenarios ranging from purely diffusive to purely advective. We conduct a morphological characterization of the resultant volcanic edifice for each case at separate times. Afterwards, we compare differences in morphological evolution, and contrast our results with already published morphometric evolution trends of radiometrically dated cones within different volcanic fields. These results are part of the EU-funded Horizons-MSCA project MECOMA (Modelling Erosion_of_scoria COnes_to_constrain Morphometry-based Ages)

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Modelling landslide dynamics of the pore-pressure induced 2012 Te Maari debris avalanche.

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Pore-fluid pressure plays a crucial role in initiating volcanic landslide and influencing material rheology during runout. A companion study (Vicente et al, in review) investigating the preparatory and triggering factors of the 2012 debris avalanche at Te Maari (Tongariro, New Zealand) suggests that the failure was likely initiated by a pore-pressure increase in the upper layers, resulting from fluid infiltration at depth. Based on this study, we explore the impacts of such initiation processes on flow dynamics and emplacement through numerical modelling. Unlike conventional dam-break models which assume an instantaneous and finite initial force imbalance to trigger landslide motion, D-Claw employs a statically balanced initial state. Motion is triggered by gradual changes, such as a basal pore-fluid pressure increase, progressively reducing the effective frictional resistance of the slope. This approach offers a more realistic simulation of natural landslides, typically triggered by rainfall, snowmelt or groundwater flow. We use D-Claw to simulate the complex flow dynamics of the Te Maari pore-pressure-induced landslide and compare the results with field data and other depth-averaged mass-flow models, including the single-phase Voellmy-Salm model and models that account for granular-fluid interactions, such as those by Pitman and Le (2005) and Pudasaini (2012). Similar to previous applications of D-Claw, such as the Oso landslide simulations (Iverson et al., 2015, Iverson and George, 2016), the Te Maari simulations demonstrate that landslide mobility is largely affected by the evolution of pore pressure during the flow, which is strongly dependent on initial conditions (e.g. initial solid volume fraction, permeability).

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Analyzing the effects of spatial gradients and temporal variability in rainfall on long-term erosion in tropical environments using landscape evolution modeling on Réunion Island, Indian Ocean

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Understanding whether long-term rainfall averages or the occurrence of low-frequency, high-magnitude events are most efficient in driving landscape erosion remains unresolved. Studies from Hawaii and the Himalayas suggest average rainfall drive erosion; while theoretical studies and field-based analysis in the San Gabriel Mountains suggest that erosion more closely follows rainfall and discharge variability. Réunion Island, a tropical volcanic island in the Indian Ocean composed of both an active and dormant volcano, represents an ideal natural laboratory to analyze the effects of rainfall on erosion. The island has uniform lithology and geologically-dated surfaces from its construction over the past 2.2 Ma, and experiences significant spatial and temporal rainfall gradients. Rainfall varies over several orders of magnitude between the leeward (~0.01 m/yr) and windward (~10 m/yr) flanks of the island. However, yearly cyclones and large storms create extreme rainfall events over the entire island. We analyze rainfall gradient effects using the stochastic-threshold stream power law landscape evolution model, which accounts for precipitation variability within the long-term erosive record. After reconstructing the non-eroded surface of Réunion for use as a simplified initial model topography, we analyze rainfall effects on drainage basin development and morphometric evolution through three test cases of increasing complexity: 1) using Réunion’s background rainfall spatial gradient from small precipitation events; 2) incorporating precipitation variability associated with large storms, and 3) adding Réunion’s general construction history to test the impact of volcanic construction and partial-resurfacing. In all models, we compare model basin morphometrics and erosion rates to Réunion Island observations.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

How does volcano internal structure and lithological contrasts control edifice erosion and morphologic evolution?

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Volcanic edifices are heterogenic landforms that represent the long-term (thousands to millions of years) amalgamation of a variety of material. Shallow magmatic intrusions construct topography from below, while effusive and explosive material erupt from the volcano, mantling the surface with deposits that have time-dependent permeable and building topography from above. Furthermore, hydrologic alteration weathers rock, weakening layers and making them more susceptible to erosion. As these processes interact to generate an edifice with a complex internal structure, stochastic erosive processes associated with climate and mass wasting erode material, further degrading the edifice. Although most landscape evolution studies consider volcanoes as homogenous landforms, how these heterogeneities influence long-term erosion patterns and morphologic evolution remains unknown. Building on previous numerical studies, we analyze the effects of spatial and depth-dependent gradients in lithology on volcanic edifice drainage basin formation and evolution using landscape evolution models that incorporate fluvial and hillslope processes. Starting from a generalized stratovolcano shape, we construct an internal stratigraphic column that consists of 1) homogeneous material with surficial lobes of less erodible material, 2) homogenous internal material with an homogenous mantle of rock with time-varying erodibility, 3) heterogenous material with a less-erodible internal core, more-erodible lithologic shell, and less-erodible cap rock, 4) heterogenous material with alternating layers of erodibility, and 5) heterogenous material with lobes of time-varying erodibility. Analyzing the morphology of the edifice and encompassing drainages, we test how these spatial gradients in erodibility correspond to volcanic landform asymmetry, drainage basin geometric heterogeneity, and drainage divide migration and stability.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Geomorphology of Rodrigues Island, Indian Ocean: implications for the Réunion hotspot

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Rodrigues Island (110 km^2, maximum elevation of 398 m) is the third youngest island related to the Réunion hotspot. Based on DEM analysis and observations from field campaigns performed in 2022 and 2024, we aim to i) infer the chronology of the island formation from its morphology, ii) reconstruct the general shape of the island prior to erosion, in order to estimate lava emission rates, and iii) constrain the landscape response time to volcanic activity. In western Rodrigues, a drowned valley, the presence of volcanic islets, and a sinuous coast line suggest an older landscape. This is consistent with recent radiometric dating and field surveys indicating that the island formed in at least two steps, the western part being the older one. Buttes capped by lava flows and paleo-valley refilling correspond to remnants of younger volcanic activity that covered western Rodrigues and formed the central and eastern portions of the island. Valleys in central and eastern Rodrigues form a simple radial drainage network with knickpoints distributed between 100 and 250 m of elevation. Most knickpoints show a rough positive power-function trend with catchment area and distance to river outlet. These knickpoints are likely related to post-eruption regressive erosion, with average horizontal propagation rates of ~1-2 mm/yr. To reconstruct the shape of the younger volcanic edifice, we use two DEM-based geometrical methods that use uneroded surfaces, such as relict portions of the original volcano flanks. We will discuss our results and their implications on the intensity of the Réunion hotspot activity.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Insights into the 2020 instability crisis of Mt Merapi through numerical modeling

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The western flank of Mt Merapi (Indonesia), one of the most active volcanoes located in proximity to populated areas, became unstable in October 2020. Surveillance techniques such as Synthetic Aperture Radar (SAR) and Electronic Distance Measurements (EDM) give an idea of the displacement magnitude. However, these remote sensing methods are limited in providing information about subsurface processes and deformation mechanisms. This limitation is critical when assessing the potential for catastrophic flank failure (e.g., Mt. Saint Helens in 1980), which remains a significant concern. Observations show a correlation between this flank movement, a NW-SE fracture crossing the entire summit, and the presence of magma within this discontinuity. In order to better understand this instability, we developed numerical models in an attempt to relate the magma pressure to the slope deformation at Mt. Merapi. In particular, relying on its ability to describe progressive failure mechanisms in elasto-plastic media, we use the Discrete Element Method (DEM) to investigate the role of the NW-SE fracture pressurization on the deformation of Mt Merapi flanks. We show here the main results of sensibility analyses performed to study the influence of the rock mechanical properties, fracture length, and magma pressure magnitude on the flank stability, comparing the resulting deformation with the 2020 Merapi crisis displacements. Despite assumptions such as material homogeneity and hydrostatic pressurization, our modeling approach allows us to make predictions not only on the potential for collapse and its kinematics, but also on the mobilized volumes, all criticall for risk assessment.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

VolcPack: an all-in-one package for volcano morphology delineation, analysis, and reconstruction

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Adequately cataloging volcanic landforms and their morphologies remains a continuously-progressing research area that is essential to understand volcano evolution, connection to underlying magmatism, and hazards. With the advent of high-resolution, easily-accessible topographic data, quantitative computational analysis has become an essential component for volcanology, allowing hundreds of volcanic features to be systematically analyzed. Various researchers have generated semi-automated programs for the delineation, morphometric analysis, and reconstruction of volcanic edifices from Digital Elevation Models (DEMs). However, these tools are often stand-alone algorithms made to accomplish one task, have inconsistent coding architectures, and are written in different programming languages. Developing a single, consistent, and standardized toolkit is an important step towards more comparable and systematic analysis of volcanic landforms. Here, we introduce VolcPack, a set of Matlab scripts for automated and user-friendly analysis of volcanic edifice morphologies. Built off of TopoToolbox, VolcPack integrates previous algorithms and introduces new components into a single, standardized package. These scripts contain four main components: 1) BoundVolc, used to identify and delineate volcanic edifices from surrounding topography through the generation of radial profiles that determine edifice boundaries; 2) MorVolc, which computes edifice morphometric parameters, including volumes; 3) DrainageVolc, designed to quantify edifice drainage basin, channel, and divide morphometrics; and 4) ShapeVolc, used to derive topographic reconstructions and eroded volumes of volcanic edifices by fitting mathematical functions to the least eroded sections of edifice flanks. In this contribution, we illustrate the capability and versatility of VolcPack for streamlined volcanic terrain analysis using examples of different types of volcanoes.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Morphology, structure and hydrothermal alteration of piggybacking crater structures at Pico del Teide (Tenerife, Canary Islands) as analysed by high-resolution photogrammetry, image analysis, and rock sample analysis

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At Pico del Teide, we investigate the overprinting geometries and vent pathways of two stacked volcanic cone and crater systems. The Las Cañadas volcano underwent repeated growth-collapse cycles, and the latest major event was a north-directed sector collapse that created the Las Cañadas Caldera. Within this collapse amphitheater, phonolitic eruptions from Teide and Pico Viejo built the older, 3500 m stratocone and crater. From here, Teide's youngest summit eruption produced characteristic phonolitic lavas and built the current cone and crater at ~3700 m, infilling the older one. Remnants of the earlier structure are visible, but details of the geometry, morphometry, and structural relationships of the crater and the overprinted cone are absent. Accessing the edifice is challenging, therefore we carried out a close-range optical, thermal, and hyperspectral drone survey in October 2024, reconstructed the morphology from 12 overflights, and identified characteristics of the evolving Teide edifice from over 20,000 images. Using structure-from-motion algorithms, we generated a digital twin of the area, from the Las Cañadas floor to the summit. From this centimeter-resolution dataset we note slope changes at scarps and distinct features within modern Teide's summit region. We perform supervised and unsupervised data classification, and map lithologies and surface structures. We compare hydrothermal deposits, thermal anomalies and structural features at the hidden (3500 m), and open craters (3700 m). Ground truthing with petrological and hyperspectral analysis at accessible sites allows us to resolve distinct lithological and structural zones, and describe the internal architecture of the piggybacking cones and craters.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Factors controlling the long-term morphological evolution of composite volcanoes through erosion: A comparison between Japan and Indonesia

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The topography of composite volcanoes results from a combination of eruptive, tectonic, and erosional processes over time. Previous studies indicate that volcano erosion patterns evolve from umbrella-like drainage networks with multiple radial narrow gullies to merging basins that widen over time. However, the factors driving long-term volcano degradation are not well understood. Different erosive processes can produce similar morphometric outcomes, while varying tectonic and climatic conditions influence the pattern and rates of volcano erosion. This study quantifies long-term morphometric variations of composite volcanoes in Japan and Indonesia, examining which parameters best correlate with volcanic activity, and how tectonic and climate variables influence these correlations. We compiled a dataset of 40 parameters for 80 conical composite volcanoes, spanning ages from 4 million years ago to the present. This dataset includes edifice morphologies and drainage basin geometries using 30 m resolution TanDEM-X DEMs. A univariate multilevel modelling approach was used to explore links between morphometry, age, climate, and the tectonic context. Indonesian and Japanese composite volcanoes show similar morphometric relationships, but Indonesian volcanoes have higher R^2 values. In the multivariate model with only morphometrics, the main flank slope significantly predicts last eruption ages, with the irregularity index being marginally significant. Adding climate and tectonic variables improves the model's predictability, making maximum temperature a significant predictor. These predictors enhance the explanation of within-country variance, highlighting the importance of country-level factors in morphologic evolution.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Submarine Explosive Volcanism at the Northern Reykjanes Ridge

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Submarine volcanic eruptions represent significant risks to coastal populations, marine ecosystems, and global transportation networks. Despite these threats, the dynamics, recurrence, and spatial distribution of submarine explosive activity remain poorly understood. This is particularly critical in shallow marine environments, where interactions between magma and seawater can lead to highly explosive eruptions capable of generating tsunamis, pyroclastic flows, expansive pumice rafts, and widespread ash clouds. We will present new high-resolution seismic reflection data that, combined with bathymetry and seabed imaging, allow us to examine the genesis of volcanic features at the Northern Reykjanes Ridge. The seismic profiles reveal volcanic edifices with low width-height ratios, stratified outward-dipping layers, and extensive volcaniclastic aprons. These features rest atop a glacially eroded unconformity, suggesting their formation during the Holocene. Our analysis indicates that many of these edifices formed through shallow explosive eruptions, with some breaching the sea surface to form transient islands documented in historical records. By comparing the seismic images of these volcanic structures with submarine volcanoes from the Azores and Aegean regions, we define the

seismic signature of three primary types of submarine volcanic eruptions: (1) deep-water explosive eruptions, (2) shallow-water explosive eruptions, and (3) Surtseyan eruptions. This classification provides a framework for recognizing eruption styles based on seismic characteristics that may be applicable globally. Our findings emphasize the potential risks of renewed volcanic activity along the Reykjanes Ridge, including tsunami generation, atmospheric ash dispersal, and the formation of floating pumice rafts.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Analyzing decadal changes of laccolith thermal features at Puyehue-Cordon Caulle, Chile using satellite, field, and drone observations to understand near surface magmatic processes

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The Puyehue-Cordon Caulle (PCC) volcanic complex (Chile) eruption of 2011-2012 formed a laccolith, a shallow horizontal magma intrusion, that caused more than 250 m of ground uplift and subsequent subsidence of 10’s of m and changes in surface temperature over time. Understanding the behavior of this laccolith can give insights into subsurface processes and potential hazards such as slope failure. We used medium resolution (90 m/pixel) Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) to create the thermal time series before, during, and after the eruption. We see decreasing surface temperatures on the laccolith for the first two years and then a steady temperature with seasonal variation. We also saw changing spatial patterns across the laccolith. We identified six distinct sections of the laccolith based on higher resolution imagery and found different parts to be cooling at different rates. To correlate these observed changes with shallow subsurface processes, we compared the satellite data with field observations and thermal and optical drome images from 2022 and 2024. We also compare thermal results from DEM differencing which found subsidence in the SE area of the laccolith. Thermal features (visible in satellite and drone images) on the laccolith are slightly offset from large subsidence signals found in DEM differencing. We interpret the thermal changes at the laccolith to be related to fractures and craters in the laccolith exposing hot regions and cooling over time.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Another Type of Pseudocrater?

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Three ocean-entry crater fields in the Galapagos Archipelago are enigmatic: the craters are too numerous and randomly distributed to have erupted above dikes or conduits, yet unlike Iceland's pseudocraters they are in settings where there is little possibility of water or soil development in the near-surface substrate. 2.9 ± 0.9 ka and 10 ± 5 ka (Mahr et al., 2016) pāhoehoe fields on Cerro Azul and San Cristobal each host > 100 spatter and scoria cones. Some craters may align with sinuous lava tubes roughly perpendicular to the coast. A ~20-m topographic bulge occurs about halfway between the vents and the coast at both localities. On San Cristobal, 10 analyzed lava samples indicate large compositional heterogeneity. At both fields, many of the craters have 'a'ā breakouts. The third locality is Bartolome, an islet off the coast of Santiago, with 15 craters, although the crater distribution there may be due to intersecting fissures. One possible origin is that steam that forms at the lava's ocean entry travels up active lava tubes until it reaches a break-in-slope, where it is trapped, and a steam–lava mixture explodes through the crust. Alternatively, two subparallel fissures erupt simultaneously. The fissure at lower elevation forms a topographic barrier, and lavas from the two fissures mix within a pāhoehoe sheet flow. Enough of a piezometric head could develop that the upper crust fails, and lava erupts through the upper crust. These pseudocraters could thus be considered mega-hornitos.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

A review on the current knowledge of tephra remobilization from scoria cone eruptions

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Tephra remobilization has proven to be an important hazard during several recent eruptions at stratovolcanoes, causing significant impact on health, environment and infrastructure. As scoria cone eruptions differ from those of stratovolcanoes in several key parameters (e.g. volume, explosivity, duration, composition, etc.), we believe that a specific study on tephra remobilization processes at these volcanoes is needed, in order to understand erosive phenomenon and related hazards in monogenetic fields. To assess the current body of knowledge on this topic, we conducted a review of the scientific literature. We found 36 articles, yet most of them focus on cone morphology, which has limited implications for hazards. The Paricutin volcano stands out for being the one case for which syn- and post-eruptive processes are thoroughly described, while studies on other volcanoes are restricted on specific aspects or only include brief mentions. The erosive mechanisms commonly identified are rill and sheet erosion and channel widening for water-related erosion, and deflation and re-suspension for wind-related erosion. The type of erosive agent (water, wind, gravity) is determined by external factors, such as climate, slope, topography, soil and vegetation. The presence of lava flows or other topographic obstacles highly promotes the accumulation of remobilized tephra. Deposits vary from massive to parallel- and cross-stratified. They tend to be well sorted and dominated by fine-ash particles that consist of scoria mixed with sediments or soils incorporated during transport. So far, there is little information available on the distribution of the deposits and the duration of the remobilization process.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Volcanic debris avalanche propagation mechanisms and dynamics: The importance of lithological properties

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Volcanic debris avalanches (VDAs) pose significant hazards due to their long runouts and destructive potential. However, the mechanisms underlying their extreme mobility remain poorly constrained, as theoretical models struggle to interpret field observations, and numerical models rely on empirical parameters to reflect their low apparent friction. This study integrates field investigations and analogue experiments to explore VDA propagation mechanisms and dynamics. Two deposits in the Canary Islands are analyzed: Tenteniguada (Gran Canaria) and Abona (Tenerife), exhibiting distinct facies and sedimentological characteristics. Additionally, the Campo di Giove rock avalanche (Italy) is also used for comparison. Structure-from-motion photogrammetry was employed to generate 3D models of outcrops and sample windows, quantifying sedimentological properties. Conceptual models of propagation dynamics were developed based on these data. Tenteniguada is dominated by competent lava lithologies, with limited disaggregation and preservation of its original structure despite brittle deformation. Its propagation involved normal fault-accommodated spreading. This is similar to Campo di Giove, dominated by limestone. In contrast, Abona comprises predominantly weak pyroclastic materials, exhibiting extensive disaggregation and microfracturing. These characteristics facilitated spreading with distributed shear. The differences in propagation dynamics are attributed to contrasting material properties and stress distribution. The Abona study supports the hypothesis that VDAs can behave as granular flows, where particle interactions govern energy dissipation and momentum transfer. Auxiliary friction-reducing mechanisms are not essential for VDA mobility. Instead, increasing momentum and kinetic

energy derived from initial potential energy can drive the flow. However, other mechanisms can also enable long runouts according to material properties.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

The Valley Palimpsest: Relicts of compounding volcanic, glacial and fluvial processes in valley systems of the Garibaldi Volcanic Belt, Canada

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The Coast Mountains of southwestern B.C. host the Garibaldi Volcanic Belt (GVB), which has an eruptive history spanning the multiple glacial, periglacial, and non-glacial periods of the Quaternary. The geomorphology of the area is heavily controlled by Quaternary period processes. The timing and magnitude of volcanic-glacial-fluvial interactions are chronicled by the landscape, especially in drainage systems that have a history of volcanism. The Cheakamus valley is one such drainage system, and is host to the Cheakamus basalts (CB), a Late Quaternary set of voluminous (1.65 km^3, ~31 km long) basalt lavas. These lavas preserve striking evidence of syn- and post-eruptive interaction with a myriad of paleoenvironments (subaerial, fluvial and/or glacio-volcanic). Previous research on the CB leave fundamental questions unanswered, including the age, source, duration and number of eruptions responsible for the Cheakamus basalts, as well as the nature of the environment of their emplacement. We combine detailed field mapping, geochemistry, textural analysis, Ar/Ar dating and paleomagnetic analysis to determine the basalt's eruptive history, and to clarify the timing and interaction of lava, glaciers and fluvial systems. Our results indicate the CB were emplaced by a single eruption of short duration, into multiple environmental conditions captured by the lava's morphology. Additional geomorphologic mapping indicates the valley system has been further and fundamentally impacted by post-glacial processes, including a previously unknown glacial lake outburst flood. The valley's mixture of primary eruptive morphologies and secondary erosive features provide a snapshot of a rapidly changing Quaternary landscape.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Developing quantitative predictive models of ignimbrite sheet architecture: a case study of the Abrigo Ignimbrite, Tenerife

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Ignimbrites are the deposits of pyroclastic density currents (PDCs), which constitute significant hazards at active volcanoes. There have been numerous recent advances in ignimbrite architecture and the sedimentation of ignimbrites, however, we know very little about PDC behaviour and ignimbrite architecture at the "basin-scale". Basin-scale models are essential in interpreting sedimentary successions and reducing uncertainty in assessing geological resources in basins. By studying the deposits in these basins we can gain insights into past terrestrial environments, climate change, tectonics and base level. Resultant deposits can vary significantly in time and space and have a multitude of different characteristics. These models use a 'systems-based' approach whereby palaeogeographic models of the basin are developed based on statistical information on characteristics such as palaeocurrent trends, grain size, channel-body and storey thickness. The architecture of the pyroclastic (and associated sedimentary) units deposited in large-volume eruptions is complex. However, by employing a quantitative systems-based approach to recent to ancient large-volume ignimbrite sheets, we can identify spatial and temporal trends and develop quantitative predictive models of distal "basin-scale" processes. This approach allows quantitative evaluation of numerous ignimbrites and effectively considers their interaction with accommodation space and response to changing base level. These analogues can then be applied to understanding the hazards posed by volcanism and the response to such catastrophic events at modern volcanoes. This work presents preliminary observations from the Abrigo Ignimbrite of Tenerife, Canary Islands, Spain.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Evolution of the Songshan complex (Tatun Volcanic Group, northern Taiwan) from geomorphological mapping, 40Ar-39Ar dating, petrology and geochemistry

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The Tatun Volcanic Group (TVG) is a cluster of young volcanic centers on the northern flank of Taiwan's capital, Taipei. It is too poorly understood to reliably and quantitatively evaluate the hazards it poses. Here we report initial results from a multi-disciplinary study of one of these volcanic centers, the Songshan complex. Analysis of high-resolution LiDAR-based topography reveals a ten-km long array of at least six overlapping lava flows that extends from Mt. Songshan northward to the coast. Several new ^{40}Ar-^{39}Ar dates reveal that these six flows erupted over about 35,000 years, between 279.8 ± 3.3 and 246.1 ± 1.3 ka. Ages of 329.7 ± 1.8 and 437.6 ± 1.8 ka on andesitic boulders within a set of younger lahars on the western flank of the flows point to still older, highly eroded and buried flows in the headwaters of the Songshan drainage. Whole-rock geochemical analyses show that the samples share the following features: (i) intermediate SiO_2 contents (54–60 wt.%), and (ii) all belong to the calc-alkaline series. Furthermore, geochemical and petrographic analyses suggest that the flows can be grouped into basaltic andesitic and andesitic, reflecting distinct compositional trends. Initial evidence suggests a dual-magma-chamber, episodic model for the Songshan complex, with compositional diversity likely tied to separate magmatic sources or evolutionary pathways. We will test this model via further examination of volcanic stratigraphy, geomorphology, and geochronology. By placing the Songshan complex within a robust framework, we will provide more reliable, quantitative assessments of the hazards posed by the TVG.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Evaluation of lahar modelling techniques for informing risk reduction practices in emergency management and critical infrastructure operation. A case study of Taranaki Mounga, Aotearoa, New Zealand.

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Lahars are a highly destructive product of volcanic eruptions, impacting the environment and society as rapid flows of water, mud, and volcanic debris. The impact of such flows on critical infrastructure can be significant and cause substantive community impacts. Lahar hazard modelling can be a method of geospatially estimating hazard intensity and extent, thereby informing risk calculations. Previous volcanic resilience engagement in Taranaki, and the global evidence base, suggests that robust and inclusive co-development of lahar risk knowledge underpins effective resilience planning. We aim to test this hypothesis by evaluating the utility of different lahar risk assessment methods in informing the development of risk information for emergency management and stakeholder use. This research aims to understand the relationship between the scientific development of lahar risk assessment methods and end user requirements when using these assessments to identify targeted risk reduction strategies. To achieve this, we will identify and evaluate what risk knowledge is most useful for end users in emergency and critical infrastructure asset management. Here, we present the initial stages of this PhD research, where we critically evaluate the use of commonly applied lahar hazard models in risk assessments that directly inform risk management strategies. We will assess whether these hazard models provide data that meaningfully contributes to our understanding of dynamic, systemic risk.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Forty years of fluvial adjustment in response to persistent volcanic sedimentation from Santiaguito Volcano, Guatemala

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Volcanoes strongly influence the hydrogeomorphic dynamics of rivers that drain their flanks. Fluvial systems affected by explosive volcanism exhibit some of the highest sediment yields observed on Earth, with much of this yield being driven by hazardous lahars. Multi-decadal, longitudinal studies of sediment transport dynamics within this context are very rare, and most prior work has focussed on the impacts of relatively short-lived sediment supply events. For the last century, the Samala River, Guatemala, has received a persistent supply of sediment due to the long-lived and ongoing development of the Santiaguito lava dome complex. This case presents an exceptional opportunity to examine the relationship between persistent but variable sediment supply, water supply, and subsequent fluvial adjustment over a multi-decadal time span. Thus, here, we present a ~40-year synthesis of remotely sensed lava extrusion rates, river aggradation rates, and rainfall, complemented by available ground-based observations.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Stratigraphy and sedimentary facies of lahar deposits at Chaitén volcano, Chile

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Chaitén volcano in southern Chile generated an explosive rhyolitic eruption in 2008–2009. Lahars with a complex combination of triggering factors and subsequent fluvial deposition of volcaniclastic sediments along the Blanco (Chaitén) River were associated with the eruption (Pierson et al., 2013; Umazano et al., 2014). The town of Chaitén is on the floodplain to delta plain approximately 10 km downstream from the volcano where the Blanco River flows into the Gulf of Corcovado, was impacted by the hazardous lahars and fluvial volcaniclastic sedimentation. Lahar deposits and fluvial volcaniclastic sediments during the past 800 years have been reported along the Blanco River (Lara et al., 2013; Umazano and Melchor, 2020). In this study, we investigated the lahar deposits and fluvial volcaniclastic deposits in the upstream of the Blanco River basin, part of which have not been described in previous studies. At least four depositional sequences are recognised,intercalated with paleosol layers; these consist of different types of flow deposits including hyperconcentrated flow deposits (sequence 4 lower), deposits with scour-and-fill structures (sequence 4 upper), muddy debris flow deposits (sequence 3), aggradational deposits with low-angle cross-stratification (sequence 2), and 2008–2009 pyroclastic density currents and lahar deposits (sequence 1). The present study reports newly obtained ^{14}C ages in the sedimentary succession including lahar deposits in the delta plain area. We further discuss the stratigraphy and correlation of these deposits and their relationship to the previous eruptions and repetitive lahar generation.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Structural continuity across an oblique rift and a transform zone in southwest Iceland.

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The South Iceland Seismic Zone (SISZ) and the Reykjanes Peninsula, located along the active plate boundary between the North American and Eurasian plates, exhibit distinct tectonic behaviors. The Reykjanes Peninsula, an oblique rift zone, experiences volcanic, and seismic activities, whereas the SISZ, a transform fault zone, is characterized by significant seismic activity (up to M_w 7) nucleating on NS-oriented faults but lacks volcanism. Both regions form a 140 km long E-W left-lateral shear zone oriented N070, with NS right-lateral strike-slip faults, indicative of a common tectonic mechanism. Structural continuity between the two zones remains uncertain, raising concerns about potential large earthquakes propagating toward the Reykjavik area. We used drone photogrammetry to map and analyze NS fault systems, producing high-resolution DEMs and orthophotos. We examined fault populations to obtain detailed structural maps. We found that 20 NS fault zones distributed in both areas exhibit comparable en-echelon fractures and compressional push-ups, supporting a structural continuity between the SISZ and Reykjanes. We then combined our results with seismic data and observed a westward decrease of fault segment lengths, earthquake magnitudes and epicenter depths. We suggest that these structural differences in the faults' systems are likely influenced by a plate boundary rotation. An angle exceeding approximately 20° between the boundary and the spreading direction, due to a higher normal component, may promote volcanic activity. This activity increases the geothermal gradient, thereby expanding the ductile area and reducing the risk of large earthquakes, which is crucial for assessing seismic hazards in this densely populated region.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Measurements of muon flux in Nirasaki debris avalanche deposit around the southern foot of the Yatsugadake volcanic chain in central Japan by using compact cosmic ray muon detectors

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The Yatsugatake Nirasaki debris avalanche deposit (200-240ka) is widely distributed on the southern foot of the Yatsugatake Volcano. The source rock mass is mainly composed of andesitic lava and pyroclastic rocks from the Paleo-Yatsugatake Mountains Period, and many huge boulders of 50-300m in size are observed. On the other hand, Cosmic ray muon is one of the elementary particles raining down from space, and have enough energy to penetrate large structures. The technology of understanding the internal structure of objects using the properties of these muons is called muography (Nagamine, K.(1995), Suzuki, K. and Kanazawa, J.(2017), Tanaka, H.K.M. and Takeuchi, H.(2014)). The three-dimensional internal structure of volcanoes and the formation process of volcanoes can be discussed by a multi-directional muographic survey (Nagahara, S. et al., (2022)). Muon detectors used in previous studies are often large and inconvenient to carry, making it difficult to measure at multiple measuring locations. There are several methods for measuring muons, but they are generally performed using a large measuring device with scintillators arranged in parallel. The device is complex and expensive, which is a barrier to its application in increasing the number of observation objects. The main purpose of this study is to investigate the usefulness of a density estimation of Nirasaki debris avalanche deposit using a compact cosmic muon detectors. The density properties of debris avalanche deposit will be discussed by using the measured muon flux.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Interpreting volcano-sedimentary processes in meta-ophiolite complex: a case study from Southern Italy

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Volcano-sedimentary successions, derived from magma outflows at mid-oceanic ridges and hot spots, largely dominate the oceanic submarine floor. However, their occurrence at great depths limits our understanding of the processes driving their emplacement. As a result, much of our knowledge comes from studying ophiolite complexes in orogenic belts. These ophiolite sequences are often accreted onto orogenies after undergoing metamorphism during ocean closure and subduction stages. Consequently, their original volcanic and volcaniclastic features may have been altered by metamorphic processes. This study addresses the challenges of deciphering volcano-sedimentary features and their emplacement mechanisms in a thick meta-ophiolite complex exposed in the Gimigliano area (Calabria, Southern Italy). The complex consists of metabasite rocks resting on a serpentinized oceanic floor and overlain by metasedimentary covers. This succession accumulated during the Jurassic opening of the Tethyan Ocean and were subsequently subjected to green-schist metamorphism, likely during the Cretaceous-Paleogene period. Detailed fieldwork, including field observations and stratigraphic log measurements, was combined with petrographic analyses of thin sections and XRD studies. This work redefines the stratigraphy of the meta-ophiolite complex, with a particular focus on reinterpreting the metabasite rock sequence through a volcano-sedimentary approach. The analysis identified effusive and volcaniclastic features and associated facies, suggesting that the metabasite rock sequence in Gimigliano could represent a succession of sheet basalts intercalated with primary volcaniclastic deposits formed by water-magma interactions. Future research will deepen our capability of recognizing volcano-sedimentary sequences in meta-ophiolites, often overlooked in the geological records, enhancing our understanding of volcanic processes occurring on oceanic floors.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

The Pliocene Paletará Caldera: the largest known eruption at the Northernmost Andes in Colombia

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Plio-Pleistocene ignimbrite deposits located at 2° N in Colombia, are evidence of a significant output of magma associated with a caldera-forming eruption in the northernmost Andean volcanic arc. These deposits are formed by a poor-sorted mixture of crystals, pumice and lithic fragments with a minimum calculated volume of 200 km^3. Based on detailed field-collected data and microscopic descriptions, a lithofacial analysis is presented as the basis of the origin and sedimentation processes associated with the deposits. The ignimbrites exhibit no evidence of long-lasting sedimentation gaps, reaching thicknesses of 230 m and covering an area of ~2000 km^2. They display a relatively uniform lithofacial distribution dominated by either welded or non-welded massive lapilli-tuff. Lihofacial variations are given by crystals, pumice, and lithic content changes. Welded lithofacies display columnar jointing and fiamme structures. Based on the results, it is proposed that the Plio-Pleistocene ignimbrites were formed by a sustained, quasi-stable, and non-homogeneous pumice flow within a fluid-scape dominated flow-boundary zone. They were deposited radially following the caldera collapse eruption and formed the Paletará Caldera 2.6 My ago. The ignimbrite deposits are formally defined as the Guacacallo and Popayán Formations and together are the evidence of the largest Pliocene eruption recorded in the Colombian volcanic arc.

Theme: 3. Volcanic processes

Session 3.5: Volcanic sedimentology and geomorphology: Understanding surface and subsurface processes in driving volcanic landscape evolution and hazards

Allocated presentation: Poster

Volcanic architecture of the Taranaki Volcanic Lineament, New Zealand: Insights from LiDAR-based terrain analysis

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The Taranaki Peninsula is characterised by the andesitic volcanic structures of the Taranaki Volcanic Lineament and its associated ringplain, which extends over 50 kilometres in diameter onshore. The subaerial volcanic edifices, including remnants such as Paritutu and the Sugar Loaf Islands, are arranged in a northwest-southeast alignment, with volcanic activity progressively younger toward the southeast. While Mt Taranaki has been dormant since 1790, most of its modern edifice was constructed over the past 7,000 years. Its ring plain, however, documents over 200,000 years of volcanic history, featuring deposits from eight large debris avalanches, along with lahars, block-and-ash flows, and ash falls. The recently captured 1-meter resolution LiDAR elevation data provides an opportunity to enhance our understanding of these volcanoes' geomorphology and volcanic architecture. Terrain analysis revealed four previously unidentified satellite vents on the Pouakai and Taranaki edifices, alongside a buried vent 6 kilometres northeast of Taranaki's summit. Additionally, our study uncovered evidence of an older, larger, and more eroded edifice with a slightly more easterly centre compared to the current summit area of Pouakai. The analysis also focused on the architecture of the Mt Taranaki edifice, including the rate of dissection, valley density, and morphometry of the planezes, to reconstruct the location and height of earlier edifices. This analysis indicates that the present summit has shifted approximately 800 metres to the west compared to the previous edifices. These findings, combined with a targeted dating campaign, could significantly enhance volcanic hazard assessments for potential future eruptions.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Talk [Invited]

Interactions between bubbles and crystals: why is it so important for eruptive dynamics ?

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Eruptive dynamics of silicic volcanoes is highly related to the possibility for gases to escape or not from the magmatic column. However, understanding and quantifying how and when this gas phase exsolves from the melt, expands and finds its way toward the surface, possibly independently from the melt, is not an easy task since it involves complex physical interactions between volatiles, melt and crystals. In order to improve our understanding of these complex mechanisms, especially during the pre-eruptive periods, we will consider evidences coming from naturals samples, numerical results as well as experimental data to highlight the role of high amount of crystals on gas content within volcanic conduits prior to eruption.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Talk

Syn-eruptive conduit processes during basaltic-andesite to dacite Plinian eruption of Raung volcano, East Java, Indonesia: insight from the textural studies of pumice and scoria

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The behavior of volcanic eruption is controlled by pre-eruptive processes in magma chamber and syn-eruptive processes during magma ascent in the conduit. Different magma composition controls the physico-chemical magma properties, leading to distinct eruptive behavior. Raung volcano in Indonesia has an interesting history, where basaltic-andesite to dacite magma caused the VEI 4-5 Plinian eruption of pumice fall (Rjp1; 0.7–1.3 km^3) and scoria fall (Rjp2; 0.3 km^3 and Rjp3; 0.1–0.2 km^3) between 1200 and 1600 CE. Our study aims to investigate the distinct eruptive processes responsible for triggering explosive eruptions in contrasting magma composition within a single volcano. We conducted petrography, whole rock geochemistry, mineral chemistry, and thermobarometry to assess the pre-eruptive processes. Additionally, textural analysis of vesicle and crystal in pumice and scoria was performed to investigate the syn-eruptive processes. Vesicles and crystals were quantified to determine vesicle size distribution (VSD), pheno-vesicle and matrix-vesicle number density (PVND & MVND), and microlite number density (MND). Our results show that both dacite and andesite eruptions were initiated by high PVND, indicating magma chamber overpressure before the eruption. Pumice fall eruption in dacitic magma resulted from the ideal condition of explosive eruption, caused by pressure accumulation of trapped gas in viscous magma. Conversely, positive correlation of MVND and MND in scoria suggests that explosive eruption in basaltic-andesite to andesite magma is related to increased magma viscosity due to microlite crystallization. These findings confirm that explosive eruptions with distinct mechanisms can be caused by variable magma composition within a single volcanic center.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Talk

Explosive eruption column dynamics for crystal-rich magmas

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Many deposits of large-volume, caldera-forming explosive eruptions involved magma with high crystal contents (~25-50 vol.%). Numerical modeling shows that such abundances of coarse crystals in an erupting mixture significantly influence eruption column and pyroclastic current dynamics compared to eruptions dominated by fine ash. In high gas content eruptions that would otherwise produce buoyant plumes/columns, abundant crystals can cause chaotic fountains (collapsing columns). Eruptions with intermediate gas content and abundant crystals can generate fountains and pyroclastic currents under conditions that would produce a buoyant plume in fine ash-only eruptions. Some conditions produce mixed behaviors involving low-altitude fallout of crystals while a buoyant fine-ash plume rises above. Crystal-rich eruptions, particularly large ones, require a new conceptual model where such eruptions can proceed directly to fountaining and ignimbrite deposition without the canonical buoyant eruption plume and basal fall unit.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Talk

Nucleation of gas bubbles triggered by shear in magmas: an experimental approach

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The nucleation of gas bubbles in magmas is fundamental to controlling the dynamics of volcanic eruptions. It is commonly assumed that nucleation is essentially the consequence of pressure drop that causes supersaturation of volatile species dissolved in the melt. Here, we examine a different mechanism: the formation of gas bubbles promoted by shear, which is ubiquitous in volcanic systems. We present analogue experiments in which liquid polyethylene oxide (PEO) containing dissolved supersaturated CO_2 is subjected to shear, in a configuration that enables us to observe nucleation in situ. At a given supersaturation pressure, gas bubbles nucleate in the PEO at a critical shear rate, which corresponds to a critical shear stress given the known liquid viscosity. This result is supported by complementary molecular dynamic simulations we performed under conditions that mimic those in experiments. Overall, our experimental results reveal that the critical shear stress for nucleation decreases as the initial volatile supersaturation increases. By expressing our results in dimensionless form in order to apply them to real cases, we show that nucleation events caused by shear are possible at a capillary number greater than 10^{-5}. This condition is met in volcanic conduits and lava flows, particularly for the most viscous magmas. These results suggest that bubble nucleation is not only caused by decompression or nanolite crystallization during ascent, but that shear also plays a role. Our results have implications for magma degassing processes, estimates of decompression rates from observed bubble size distributions, and predictions of eruptive styles.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Talk

The explosive eruption of carbonatite and associated pyroclast textures

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Explosive eruptions of low-viscosity lava, such as basalts and basanites, are widespread and are a dominant form of volcanism on Earth. They commonly display Hawaiian and Strombolian eruption styles and are relatively well documented. Carbonatites are another magma composition, that are also characterised by low melt viscosities. However, their eruptions are much less frequent, and observations of explosive carbonatite eruptions are minimal. Here, we examined the textural features of carbonatite pyroclasts from the Miocene Kaiserstuhl Volcanic Complex, which hosts both intrusive and extrusive suites of carbonatite rocks. Three pyroclastic rock samples from the Kirchberg and Hechtsberg regions of the complex were studied using optical petrography, scanning electron microscopy, and image analysis techniques. Our observations show that the pyroclasts, after primary fragmentation, aerodynamically deformed in flight and experienced pyroclast-pyroclast collisions to form complex, agglutinated pyroclasts. Further image analysis has enabled us to reconstruct the primary grain size distribution, representing primary pyroclast formation and their textural features before agglutination. Finally, these data are used to inform on the fragmentation processes and intensities of explosive carbonatites eruptions. **Keyword:** carbonatite, in-flight deformation, agglutination, textural features, grain size distribution

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Talk

Extensional Rheology of Crystalline Magma

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During magma ascent, bubble growth can be significantly hindered by the surrounding melt+crystal matrix, affecting volcanic eruption styles. The growth of bubbles imposes an extensional stress on the surrounding matrix. Thus, while bubble growth dynamics is significantly affected by the rheology of the crystalline melt under extension, it remains poorly constrained. In this study, we use dynamically similar analog experiments to investigate crystalline magma rheology under extension. The suspensions up to 0.64 volume fractions of particles were prepared using 10 Pas silicone oil and hollow glass spheres (7–13 μm diameter). Using a linear drive in a rotational rheometer (Anton Paar MCR 702e), extensional tests were performed where samples were stretched following an exponential velocity profile to produce a purely uniaxial extension. Suspensions with ≤0.50 and 0.64 particle volume fractions (near maximum packing) were stretched following the capillary breakup extensional rheomtery (CaBER) and filament-stretching rheometry (FiSER), respectively. The change in mid-diameter of the sample filaments was determined by analyzing the experimental videos in ImageJ. Additionally, shear rheology experiments of the same particulate suspensions were performed using parallel plate geometry. The stress-strain rate data were fitted to the Herschel–Bulkley model. The shear rheology data shows that increasing particle fractions increases viscosity and yield stress while decreasing the flow index of the suspensions. Our preliminary results show that the shear and extensional rheology of crystalline magma are broadly comparable. Future experiments will investigate the effect of crystal shape on the extensional rheology to further inform the magma ascent dynamics during volcanic eruptions.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Talk

Predicting Bubble Number Density in Magma

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Volcanic eruptions are driven by the formation and growth of gas bubbles that exsolve from the melt as it rises to the earth's surface. Bubble formation is favoured by supersaturation, which provides the thermodynamic driver for nucleation, and opposed by surface tension, which gives a free energy cost of to the melt-gas interface. Experimental data has shown that substantial supersaturation is needed to overcome this energy barrier to form bubbles in the bulk melt (i.e. homogeneous nucleation). The presence of crystals in the melt has been shown to reduce the supersaturation needed to form bubbles by reducing the energy barrier to form the phase interface (i.e. heterogeneous nucleation). We present a numerical model for nucleation in a decompressing melt. We combine classical nucleation theory with a probabilistic approach to predict the stochastic formation of bubbles. Heterogeneous nucleation is captured via a reduction in the energy barrier associated with nucleation on a crystal. The model predicts the evolution of the distribution of bubbles in space and time using a Voronoi approach, in which supersaturation at potential nucleation sites is modified by progressive diffusion of volatiles into neighbouring bubbles. The model accurately predicts the evolution of bubble number density observed experimentally in rapidly decompressed, magnetite-bearing melts, across a range of total decompressions. At low decompressions (<20 MPa) we observe incomplete nucleation, with bubbles forming only on some crystals. At moderate decompressions (20-80 MPa), one bubble nucleates on every crystal. At the highest decompressions (>80 MPa) we predict homogeneous nucleation between the crystals.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Investigating transitions in eruption style at ocean island volcanoes using XCT analysis of bubble textures

Amy Kember*[1]

Margaret Hartley[1]

Margherita Polacci[1] Elizabeth Evans[2] Lucia Mancini[3] *[1]Department of Earth and Environmental Sciences, The University of Manchester, M13 9PY, U.K. [2]Henry Moseley X-ray Imaging Facility, Alan Turning Building, Manchester, M13 9PY, U.K. [3]Slovenian National Building and Civil Engineering Institute, 1000 Ljubljana, Slovenia* Transitions in eruption style can be driven by the behaviour of magmatic volatiles in the shallow volcanic conduit. Although volatile exsolution and degassing dynamics cannot be observed directly, records of these processes may be discerned through quantitative study of vesicle textures within tephra samples. X-ray Computed Tomography (XCT) offers a micron-scale, non-destructive means for analysing vesicle morphologies and size distributions within pyroclastic rocks. The 2021 Fagradalsfjall eruption in southwest Iceland exhibited significant changes in eruptive style. Initial stages consisted of near-continuous effusive activity with mild, intermittent lava fountaining from multiple fissures. By 28 April sustained lava fountaining had been confined to a single vent. After 2 May, activity became cyclical where periods of inactivity alternated with intense lava fountaining. This eruption provides an ideal opportunity to test if the vesicle textures within samples acquired from contrasting and well-constrained phases of activity can be indicative of different degassing mechanisms which may have determined the eruption style. Five lapilli clasts from representative samples acquired during distinct eruption phases have been analysed by XCT. We present and compare bubble size distributions (BSDs) obtained for each clast. We discuss how the BSDs may be interpreted according to models which can be applied to basaltic pyroclasts to elucidate the modes of bubble nucleation and growth. Consideration is given to post-eruptive processes which may overprint the signals from the conduit. We correlate these outcomes with surface observations to propose which degassing regimes may have been operative during each eruptive phase.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

An oscillatory rheology measurement of crystal-bearing molten magma

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The rheology of magma determines the ease of magma movement, which governs the possibility and style of eruption. Rheology includes both the viscous and elastic components of deformation. The viscosity of magma has been measured, but there are limited measurements of rheology. Oscillatory rheology measurements, imposing the sinusoidal strain and measuring the stress and its phase shift simultaneously, provide viscosity, elastic modulus, and their ratio. Further, magmas with temperatures below the liquidus have crystals, and the jamming framework of crystals may create complex rheology, as commonly observed in dense suspensions. Here, we conduct oscillatory rheology measurements of crystal-bearing high-temperature magma with a basaltic-andesite composition. Our measurements show that the magmas with a crystallinity of around 50 vol.% have solid-like behaviors and transition to liquid-like when the strain amplitudes become large enough. Silicic magmas are Maxwell fluids and show elasticity under rapid strain rates, which is different from our samples with a low-viscosity melt phase. In addition, the measured elastic modulus in our measurements is lower than that of the silicic melt measured at high frequencies. These results suggest that the jamming network of crystals generates the elasticity of the partially molten magma.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Experimental analysis of slug regimes using kymography.

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Gas slugs, or Taylor bubbles, are massive bubbles that drive discrete and cyclic Strombolian explosions. This style of eruption is one of the most widespread expressions of uninterrupted basaltic sub-aerial volcanism globally. To understand the mechanisms driving observable surface eruption dynamics, we must first understand the flow dynamics in the shallow (<1 km depth) plumbing system. Our current knowledge of the fluid dynamics of ascending slug trains in volcanic conduits is built upon an extensive foundation of experimental studies, where bubbles behave similarly to those in low-viscosity basaltic magmas. Understanding how slugs flow in pipes is important to many fields, and thus the accurate measurement and analysis of their parameters is equally essential. Here, we introduce a novel application of kymography – an existing digital image processing technique typically used to track micron-scale processes in biological and medical research – for use in the measurement of continuous slug flow in cylindrical pipes. Kymographs allow the flow processes that are captured across thousands of frames of experimental footage to be represented as space-time data in a single image. We describe the method for generating and analysing kymographs from flow experiment footage using the freely accessible image analysis software ImageJ. Kymographs are demonstrated to be an effective low cost and accessible tool for the measurement of bubble and coalescence event counts, gas and liquid slug velocities, bubble length and diameter, gas volume fraction, and to indicate steady state ascent.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Chemical and textural analysis of tube forming lavas at Vesuvius (Italy) by EMPA and 3D X-ray micro-CT

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Lava flow emplacement is directly affected by effusion rate, viscosity and topography. The transport of lava within the flows is also enhanced by the formation of lava channels or lava tubes. Indeed, a tube-fed lava flow can emplace over longer distances, due to the insulation of the molten lava by the roof preventing cooling by atmospheric heat exchange. The formation of lava tubes in a lava flow depends on numerous parameters such as eruptive rates, pre-eruptive topography, geochemical composition, vesicles and crystals content, and ultimately, viscosity. Thus, it is crucial to understand the mechanisms governing lava tube formation to improve hazard assessment and crisis response. Here, we examine a lava flow field formed during the 1858-1861 eruption at Vesuvius within which a series of lava tubes were formed. We sampled the 1858 lava flow field and one of its lava tubes, conducted Electron Microprobe Analysis (EMPA) to measure crystal and glass compositions, and performed a 3D morpho-textural characterization using phase-contrast synchrotron X-ray computed microtomography (μ-CT) to retrieve the 3D structure of our samples and characterize the crystal phases. We found variations in Crystal Size Distribution (CSD) within the microlitic matrixes that reflect the cooling conditions of the lavas during emplacement. We also observed variations in the volume fraction of the phases between the samples. These variations in crystallinity within the flow field and lava tube give insights into the conditions of emplacement of the lava flow field and the formation of lava tubes by inflation.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Textures, formation and implications of palisade bubbles within felsic pyroclastic products

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Bubble textural studies provide a snapshot into pre- and syn-eruptive processes occurring within magmas. A distinctive feature, where bubbles form a coarsely vesicular sheath around crystals within felsic pyroclasts, is known as palisade texture. It indicates early bubble growth that implies volatile saturation with bubble nucleation occurred on phenocrysts, either stably within the magma chamber or during the earliest slow stages of magma rise prior to general nucleation of bubbles in the melt. Subsequent decompression of the supersaturated magma causes expansion of these pre-existing bubbles to form the characteristic palisades before the runaway nucleation of bubbles occurs in the groundmass glass. While these textural features have little documentation, they hold the key to understanding pre-eruptive magmatic conditions within large felsic systems. Previously documented for (small) Fe-Ti oxide crystals, we present images of palisade textures from larger (mm-scale) quartz, feldspar and pyroxene phenocrysts. Using 3D Micro-Computed Tomography and 2D SEM imagery, we investigated 150 rhyolitic, dacitic and phonolitic pyroclasts from New Zealand, Germany, the USA and the Kermadec Arc for the presence of palisade bubbles, documenting the natural variability of internal bubble structures to develop a classification guide. Palisade bubbles often pull apart the crystals they surround, forming thin glass connections within the gaps and form augen structures within the distorting and flowing groundmass bubble textures, the latter suggesting that they were more viscous. Results from this study will contribute to better understanding the timescales of volatile supersaturation and magma ascent rates within felsic systems that produce explosive eruptions.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

The Multiphase Viscosity of Lava: New Insights from Combining Laboratory and Field Measurements

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Laboratory rheometry on remelted volcanic rocks is the standard technique for measuring lava flow properties. This approach enables precise measurements but struggles to recreate the natural lava emplacement conditions. Particularly, natural lavas erupt as multiphase suspensions (melt + crystals + bubbles), however, standard laboratory methods cannot retain gas phases, and experiments are limited to two-phase (melt+crystals) suspensions. Furthermore, the oxygen fugacity of lavas is known to influence the kinetics of crystallization, and despite its importance, few studies to date have considered this factor. Currently, the only technique to measure the three-phase rheology of lava is through in-situ measurements while it is flowing. Here we present the first study that integrates viscosity data from laboratory-derived single, and two-phase measurements with three-phase suspension data from field measurements on the 2023 Litli Hrútur eruption in Iceland. We present a multiphase rheological characterization of remelted crystallizing lavas at subliquidus temperatures, and thermal equilibrium, measured at log fO2 of −9.15, and deformation rates relevant to natural processes. We compare these measurements to in-situ field viscosities and find that our values overlap in temperature (1165-1150 ̊C) and viscosity space (2.5-4.5 Log Pa s) across cooling rates of 0.5-1 ̊C/min. We find that equilibrium laboratory measurements recreate comparable crystal volumes to natural samples (~20-50%), yet the associated viscosities are much higher in the laboratory than what was recovered in the field. This comparison allows the first quantification of the effect that bubbles have on reducing the effective viscosity of natural lavas.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Influence of bubbles on the extensional rheology and fragmentation of magma

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Fluid fragmentation dynamics govern the formation of pyroclasts in eruptions of low-viscosity magma such as basalt. This is in contrast to the relatively well-studied brittle fragmentation dynamics of more viscous eruptions. Understanding the fluidal or ductile fragmentation of magma is necessary for modelling potential tephra production during eruptions, and for interpreting past eruption characteristics from tephra deposits. The fragmentation of low-viscosity magma depends on its extensional rheology (i.e., its response to being stretched), which is fundamentally different to its rheological behaviour in simple shear. When magma is stretched, it forms a narrow filament, and a balance between surface tension and viscosity determines the maximum filament length and lifetime, influencing pyroclast production. The extensional rheology of Newtonian fluids is well-established, but erupting magmas are typically non-Newtonian due to the inclusion of gas bubbles, with basaltic tephra often containing up to 80% bubbles by volume. Here, we explore the effect of bubbles on extensional rheology and fluid fragmentation using analogue experiments. We create a range of bubble suspensions in well-characterised Newtonian fluids (e.g., silicone oils), and investigate the extensional rheology by rapidly separating two small plates, stretching the bubbly fluid into a narrow filament between them. Using a high-speed camera, we observe the dynamic response of bubble shapes and their spatial organisation, measure the time at which the filament breaks, and extract an apparent extensional viscosity based on the change in filament width. Our results demonstrate that bubbles play a crucial role in the fragmentation of low-viscosity magmas.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

The 62.5 Ma Dongri-Uttan rhyolite sequence, Mumbai area, Panvel flexure zone: late-Deccan effusive-explosive silicic eruptions during India-Seychelles continental breakup

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Post-K/Pg boundary (Danian-age) Deccan magmatism is well exhibited in the western side of structurally complex Panvel flexure zone. The metropolitan city Mumbai shows multifaceted geology aligning with main Deccan magmatism like tholeiitic lava flows and dyke, and some of the atypical geological features like spilitic pillow basalts, ash constituted "intertrappean" sedimentary deposits and trachyte with or without basaltic enclaves. The study focuses on area Dongri-Uttan area, characterized as densely vegetated low-lying region in northwestern Mumbai. Most of the magmatic units dated to be of 62.5 to 61 Ma, are contemporaneous with or slightly postdate the 62.5 Ma India-Seychelles continental breakup and Panvel flexure formation. Sheth and Pande (2014) reported the $^{40}Ar/^{39}Ar$ plateau ages of the columnar rhyolites in Darkhan Quarry and near Uttan-Sagari police station (USPS) to be 62.6 ± 0.6 Ma and 62.9 ± 0.2 Ma (2σ errors). They also reported the highly altered 2-3 m thick sedimentary deposit in USPS section. Recent excavations reveal lower columnar rhyolites and, suggests the indistinguishable ages are of two distinct columnar rhyolites separated by the well-bedded silicic ash. The upper rhyolite lacks basal autobreccia, and in petrographic studies show snowflake texture without any vitroclast, but the ash present in between constitutes glass shards and pumice clasts. We interpret the ash to be explosively formed Plinian fallout deposit of low-grade vitric ash. The USPS lava-tuff-lava sequence of 62.5 Ma provides evidence for the rapid silicic eruptions switching from effusive to explosive to effusive behavior, in the western Indian rifted continental margin.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Slug formation in basaltic eruptions driven by rapid coalescence of bubbles

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Bursts of decameter-sized bubbles are commonly observed during basaltic eruptions. These giant bubbles are thought to form through the coalescence of smaller bubbles within the volcanic conduit, driven by buoyancy forces resulting from the low viscosity of basaltic magma. Understanding the dynamics of buoyancy-driven bubble coalescence is thus essential for estimating the explosivity of basaltic eruptions. In this study, we investigate the evolution of the bubble volume distribution by considering both buoyancy-driven coalescence and bubble expansion due to decompression. Our findings reveal that, at lower decompression rates, the bubble volume distribution quickly evolves into a power-law form, where the number of bubbles scales with the inverse square of the bubble volume. This suggests that repeated bubble coalescence in basaltic magma can generate large bubbles within a timescale of 45 minutes to 3 days. Furthermore, we analyze the occurrence of eruption styles, specifically Strombolian and Hawaiian, under the assumption that slug bursts drive Strombolian eruptions. From this analysis, we identify a critical magma ascent velocity that governs the transition between these eruption styles, aligning well with observed style transitions at Izu-Oshima and Kilauea.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

A rheological map of Mauna Loa Basalts

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Rheological data are crucial to modeling the storage, transport, eruption, and emplacement of magma and lava. Magma and lava transport processes generally occur at subliquidus conditions, where the melts crystallize, and at lower than atmospheric oxygen fugacities (fO_2). Yet, the effect of oxygen fugacity on sub-liquidus rheology remains largely uncharted. Surprisingly, to date, there are no direct rheological measurements for Mauna Loa, the largest active volcano on Earth. We present the first complete rheological characterization of Mauna Loa lava, based on samples from its latest eruption in 2022. We map its rheology across the solidification interval at both oxidized (in air) and reduced (log fO_2=-8.7) conditions. These measurements constrain the pure liquid viscosity and map the lava's rheology during crystallization in both thermal equilibrium and at cooling rates between 0.25 and 3.00 C/minute. We find that for Mauna Loa the solidification interval is significantly narrower than for Icelandic and Etnean basalts. In respect to oxidized conditions, we observe that at reduced conditions: 1) the onset of crystallization is delayed in both time and temperature, 2) crystallization is suppressed by up to 50 °C, 3) the crystallization kinetics are slower, 4) the composition of the crystallized phases changes, 5) the volume fraction of crystals decreases and, with that, the effective suspension viscosity decreases as well. The resulting rheological map constrains the minimum and maximum effective lava viscosity applicable to Mauna Loa lavas and can help guide physical property based lava emplacement models that aid in eruption response and hazard assessments.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Numerical simulation of nucleation, growth, and coalescence of bubbles in magma

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Vesicle textures in volcanic pyroclasts have been useful for understanding the subsurface vesiculation process in magma. However, it is not easy to interpret vesicle textures because they are time-integrated products of a complex sequence of nucleation, growth, and coalescence of bubbles in magma. Here, we developed a new numerical simulation of these three processes and investigated how bubble size distribution in magma evolved with decompression. The new model incorporated the unsteady feature of the diffusion profile around growing bubbles. This unsteady growth greatly reduces the supersaturation, which in turn decreases the bubble number density after decompression. The bubble number density predicted by our model is more consistent with the results of decompression experiments than a previous model assuming the steady diffusion profile. We also proposed a new coalescence kernel for growing bubbles, based on film drainage timescale. As bubble coalescence proceeds, the distribution of bubble size gradually gets wider. The width of bubble size distribution is comparable with the reported data of the decompression experiments. Contrary to previous simulations that required a long computational time of several hours, our new simulation requires only several tens of seconds. This kinetic model can be a powerful tool for assessing the nucleation, growth, and coalescence of bubbles in magma.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

In-situ degassing of natural crystal-bearing silicic magmas

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Bubble growth dynamics in silicic magmas determine magma storage ability in the crust and its transport through the Earth's crust to the surface. Bubble formation and growth in magma is typically driven by magma decompression and/or heating upon ascent, where neighboring bubbles tend to interact, deform and/or coalesce during growth. Crystals are present in all natural magmas in variable quantities. However, the effect of different crystal types, sizes and shapes on the degassing dynamics of crystal-poor silicic magmas remains barely studied. In this work we explore bubble growth dynamics in different natural crystal-poor obsidians via heating experiments coupled with *in-situ* 4D visualization using time-resolved synchrotron-based X-ray tomography. Experiments show a clear control of crystals (phenocrysts and microlites) on bubble spatial distribution even at low crystal volume fractions. Coalescence is observed in phenocryst-bearing samples and bubble growth kinetics differ from those observed in phenocryst-free obsidian and predicted by bubble growth modelling. On the other hand, the distribution of oxides microlites seems to control the distribution of nucleated bubbles. These results shed light on the influence of different crystalline phases on the spatial distribution of bubbles. The time resolution of a few seconds allows us to capture highly transient bubble interactions that have consequences on the dynamics of magma degassing during ascent with potentially strong implications for eruptive behaviour.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

The effect of microlites on the extensional rheology and fragmentation of basaltic magma

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Basaltic magma typically erupts in an effusive manner, or sometimes with mild explosivity associated with lava fountaining or Strombolian activity. Pyroclast formation in these conditions is governed by fluidal or ductile fragmentation, as opposed to brittle fragmentation which occurs in eruptions of more viscous magma. However, some basaltic eruptions are known to have been more explosive, even Plinian, making them comparable with more viscous eruptions. One potential cause of explosive basaltic behaviour is the crystallisation of microlites, which increase the magma's viscosity, allowing it to fragment in a brittle manner under plausible conduit conditions. Here, we present results from laboratory experiments exploring the extensional rheology and fragmentation of particle suspensions analogous to microlite-bearing magmas. The rheology of particle suspensions in simple shear has been studied extensively, but extensional rheology has received much less attention. Extensional conditions occur at a range of scales during basaltic eruptions; for example, as pyroclasts separate within lava fountains, or as bubbles expand during magma decompression within the conduit. We explore how the volume fraction of solid particles within a Newtonian fluid phase influences the extensional rheology, breakup dynamics and fragmentation efficiency of the bulk suspension. Lastly, we evaluate the propensity for these particle/microlite induced dynamics to occur during the eruption of basaltic magmas.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Effect of bubble dynamics in driving explosivity of peralkaline trachytic/phonolitic magmas

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Explosivity of rising magma is influenced by conditions established at the storage level, but is within the magmatic conduit that magma's fate is determined. Peralkaline magmas (agpaitic index > 1) exhibit high water saturation levels, providing sufficient fuel to drive explosivity. At the same time, their low viscosities—resulting from alkali-induced silica depolymerisation—impede fragmentation conditions compared to high-silica calc-alkaline magmas. Yet, peralkaline magmas can still produce violent eruptions, as evidenced by numerous trachytic and phonolitic documented events. The Rungwe Pumice eruption (Tanzania) serves as a striking example of unexpected eruptive behaviour. This Plinian VEI 5 eruption was generated by a crystal-poor, microlite-free phonolitic/trachytic magma stored at high temperatures and low water concentrations, indicative of shallow storage depths. Under these conditions, likely milder eruption intensity is expected. However, detailed 2D and 3D textural analyses of pumice ash clasts, reveal delayed homogeneous bubble nucleation (ΔP~50MPa) occurring abruptly at shallow depths (P_n~17 MPa) due to fast ascent rates (1-2 MPa). The rapid nucleation and growth of bubbles left insufficient time to form a highly vesicular foam (f < 75%), while low magma permeability hindered efficient outgassing. This maintained a strong coupling between magma and gases, and, combined with a sudden rheological shift likely triggered by volatile loss and a temperature drop, ultimately led to fragmentation and the explosive nature of the eruption. The Rungwe Pumice eruption highlights the critical role of conduit dynamics in shaping the behaviour of peralkaline magmas, which can unexpectedly deviate from predictions based solely on their composition and storage conditions.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Textural evolution of pyroclastic products of the Villarrica volcano between 2015-2024: insights into its eruptive style transitions

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Style transitions are common during volcanic eruptions but the processes that trigger them remain poorly understood. Understanding these transitions is essential regarding hazards, as they can exacerbate the associated risks. Vesiculation plays a fundamental role in magma dynamics and the resulting eruptive style. The content, size, shape, and distribution of vesicles in volcanic rocks record magma processes and can be correlated to conduit processes and subsequent eruptive behaviour. In this work, we studied the vesicle textures of 20 basaltic and basaltic andesite pyroclasts produced by the Villarrica stratovolcano between 2015 and 2024. Villarrica is the highest-risk and most active volcano in Chile. It has exhibited various eruptive styles ranging from VEI 0 to 3 during its historical activity, displaying Strombolian, Hawaiian and lava fountaining activity. In March 2015, Strombolian activity progressed quickly into a 1.5-km-high lava fountain. After that event, the activity continued shifting intermittently between Strombolian explosions and the open conduit degassing from the active lava lake. We performed textural analyses, including measurements of vesicularity, vesicle shape, number density, and connectivity on three-dimensional volume reconstructions obtained via X-ray computed microtomography. We complemented this method with scanning electron microscope image analysis and bulk-rock compositions. The results provide insights into the textural evolution of the volcanic products related to distinctive eruptive behaviours observed at the surface and with magmatic processes that could trigger these changes. These processes could be related to changes in the degassing rates and/or mechanisms in the conduit or other processes occurring in the shallow plumbing system.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Exploring Textural Signatures of Submarine Volcanism in Rafted Pumice from the 2019 Eruption of Volcano F, Tonga

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Submarine eruptions can produce swaths of floating pumice (pumice rafts). These rafts, measuring tens to thousands square kilometers, can be a hazard for marine and coastal infrastructure. They can also preserve volcanic deposits which might otherwise be difficult to access on the seafloor. As such, rafts provide an opportunity to quantify the bubble textures of submarine pumice, which can elucidate bubble nucleation and growth dynamics at submarine eruptions. In August 2019, "Volcano F," a submarine volcano located along Tonga-Kermadec Arc, produced a 195 km^2 pumice raft that was sampled at sea near the vent (50-200 km) and distally (900 km). We quantify the connectivity (c) and total porosity (ϕ) of 45 pumice lapilli by helium pycnometry. Results reveal abundant isolated porosity in high total porosity pumice ($\phi > 65\%$, $c < 0.6$). Based on a literature review of 2300 pairs of total porosity-connectivity measurements in volcanic pumice, we deem this texture rare at sub-aerial eruptions but common at submarine eruptions. To explore the texture further, we analyze X-Ray Computed Tomography images of 7 breadcrusted pumice, with abundant isolated pores, from rim to core. We find that clast total porosity increases from rim to core and that isolated pores are more abundant in clast rims, which is consistent with rapid quenching of an outer rim due to interaction with external water. Abundant isolated pores are also present in clasts without breadcrust textures. Thus, more work is needed to understand limits on bubble nucleation, growth, and coalescence in submarine settings.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Bubble throat growth rates and the development of dynamic permeability in crystalline magma

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Pyroclasts typically exhibit coalesced vesicle textures, which are the evidence of bubble coalescence and the incomplete bubble wall retraction in magma during volcanic eruptions. The sizes of bubble throats or inter-bubble apertures in permeable networks control the extent of magma outgassing, and thus, affecting the volcanic eruption styles. Therefore, quantifying the growth rates of the bubble throats is important but has remained poorly constrained. Using dynamically similar experiments with spontaneous bursting of a single bubble in rheologically well-characterized particulate suspensions, we investigate the growth rate of bubble throats for a range of particle volume fractions. For suspensions with $\lesssim$0.50 particle volume fraction, a circular hole (bubble throat) forms following bubble bursting, which after an initial fast growth starts plateauing at a throat-bubble size ratio of $\gtrsim$0.20. The throat growth time scale overall increases with increasing particle volume fraction due to the increase in suspension viscosity. On the other hand, bubbles in suspensions with particle volume fractions near the maximum packing fraction (~0.64) exhibit a fracture-like opening. Our experimental results suggest that the plateauing of the bubble throat growth in crystal-poor to crystal-rich magma likely contributes to the wide occurrence of the incompletely retracted vesicle walls in pyroclasts. Thus, the outcomes from this study provide better insights into the time-dependent loss of gas from crystallizing magmas. The implications of the flow- to fracture-like growth of bubble throats on the development of dynamic permeability in magma are discussed.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

A constitutive equation for the viscosity of bubbly magmas

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The eruptive dynamics of a volcano are largely determined by the rheology of its magmas. Bubbles in magma have been shown to either increase or decrease its viscosity, primarily depending on the balance between the viscous stresses that deform the bubbles and surface tension which acts to restore their sphericity, encapsulated by the Capillary number. Despite the growing number of experimental studies investigating the rheology of bubbly fluids, a definitive constitutive relation between the viscosity η of a magma and its bubble volume fraction ϕ is still lacking. Here, we show results of new viscosity measurements on rhyolitic magma at high Capillary numbers, with bubble volume fractions between 0.15 and 0.80. We deformed pumice samples from Medicine Lake Volcano, California in combined torsion-compression experiments at a temperature of 975 °C and shear strains up to ~3. Based on our experimental results, we define a new constitutive relation for the

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Formation of obsidian by resorption of volatiles during slow cooling

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The very glassy nature of obsidian has led to the idea that it is formed through rapid cooling. The near absence of vesicles, however, is problematic, as it requires complete degassing and outgassing of the parent melt. Here we show that dense obsidian can be produced by resorption of bubbles during slow cooling. We performed *in-situ* experiments in which melt with low H_2O content was first heated (lowering solubility) then cooled (raising solubility) during 3D tomographic imaging. Data for the solubility-driven growth and resorption of bubbles were used to validate a numerical model of the process. We use the model to explore the conditions under which rhyolitic melt can resorb bubbles completely during cooling, to form dense obsidian. At atmospheric pressure, melt with low initial gas fraction $\phi \approx 0.05$ (typical of lava formed by sintering) can form obsidian at relatively fast cooling $\approx 10^{-4}$ K/s, corresponding to cooling from eruption temperature to the glass transition temperature T_g in around a month. Under the same conditions, melt with higher initial gas fraction $\phi \approx 0.3$ (typical of lava formed by outgassing of a permeable foam) can form obsidian at cooling rate $\approx 10^{-5}$ K/s, corresponding to cooling to T_g in around a year. Modelled resorption timescales are consistent with observations from natural obsidian lavas. Our results indicate that resorption is a viable mechanism for the removal of bubbles during obsidian formation and demonstrates that cooling must be slow enough to allow gas to resorb, challenging the popular idea that obsidian requires 'fast' cooling.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

The role of bubble-crystal interactions in the eruption dynamics of alkaline magmas: implications for Vesuvius volcano

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Eruption dynamics and eruptive style are controlled by the interplay and feedback of non-linear conduit processes during magma ascent, such as gas exsolution, bubble expansion, outgassing and crystallisation. These processes control the evolution of magma viscosity and how easily the gas and melt phase decouple during ascent. Volcanism associated with intermediate and evolved alkaline magmas (from phonotephritic to phonolitic) is characterised by a wide range of eruptive styles, from lava flows to Plinian eruptions. This diversity in eruptive behaviour makes the eruption dynamics of alkaline volcanic systems challenging to predict. The volcanic history of Vesuvius (Italy) is characterised by complex transitions in eruptive behaviour, producing eruptions that are amongst the most catastrophic volcanic eruptions in human history. Here, we combine synchrotron X-ray microtomography with a numerical conduit model to investigate the processes and the pre-eruptive conditions that control the style of activity of alkaline magmas, using Vesuvius as a case study. We quantify crystallinity, vesicularity and connectivity of pore networks in pyroclasts from deposits of the 79 AD Plinian eruption and of the 1944 lava fountaining eruption of Vesuvius using 3D textural analysis. Our results reveal that heterogeneous bubble nucleation, driven by leucite crystals, contributes to the formation of large bubble populations during Plinian eruptions, with vesicle number densities exceeding 10^4 mm^{-1}. The numerical results, obtained using a 1D steady-state model, indicate that phonolitic

magmas are prone to fragmentation considering a wide range of pre-eruptive conditions, including temperatures from between 830 and 970 ºC and crystal fractions up to 0.40.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Toward an experimentally validated kinetic model of polydisperse bubble population dynamics

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A growing number of natural and experimental evidence shows that the variety of eruptive styles is intrinsically linked to micro-scale bubble dynamics. Nevertheless, the coupling of realistic micro-scale models for bubble dynamics and fluid dynamics of large-scale magma flow remains a challenge, due to the very different characteristic length and time scales. Moreover, while large-scale flow models are well-established and widely used, further advancements are needed to model bubble dynamics at the micro-scale. Most bubble dynamics models neglect the polydispersity (i.e., non-uniformity) of the bubble distribution and the experimental validation remains a critical aspect. Conventional "black-box" experiments used for validation provide a snapshot of the final state of the bubbly magma, at the end of the experimental run, but do not allow observing the temporal evolution of the bubble population. Here, we present a new kinetic model that describes the time evolution of a polydisperse population of gas bubbles in magma due to nucleation, growth and coalescence. The model is suited for incorporation into large-scale flow models. For validation, we re-analyzed literature data from "in situ" experimental observations of the time evolution of the distribution of the bubble population in a degassing magma. To analyze the experimental videos we developed a code for automatic image segmentation and rigorous statistical analysis. Preliminary results show that the model can capture the growth and coalescence of the bubble population and that "in situ" experiments represent a powerful approach for studying bubble dynamics and validating micro-scale models.

Theme: 3. Volcanic processes

Session 3.6: Crystals and bubbles in magma: Understanding their formation, interaction, feedbacks and effects in magma properties and eruption behaviour

Allocated presentation: Poster

Insights into fragmentation and densification processes from a fossilised shallow conduit on the flank of the Nevados de Chillán Volcanic Complex

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Eruptive style transitions are common in silicic volcanoes and an improved understanding of transitional controls is necessary for hazard forecasting. Examples of hybrid eruptions where explosive and effusive behaviours occur simultaneously have led to a re-examination of models used to understand these complex processes. We present a conceptual model of the evolution of a narrow (2.5 m wide) conduit located on the SW flank of the Nevados de Chillán Volcanic Complex, Chile. This conduit records evidence of fragmentation and densification processes through intercalated and juxtaposed banded, porous and dense domains. We combined qualitative textural analyses at different scales, vesicle size and shape, connected porosity using helium pycnometer and total water content using Fourier transform infrared spectroscopy. The results allow us to identify five principal phases of the conduit evolution: (I) an explosive phase where the conduit is filled with pyroclastic material, (II) a cyclic process of fragmentation and densification within the conduit that generates intercalation of the porous and dense domains, and leads to a hybrid explosive-effusive phase, (III) the formation of a dense magma plug that eventually seals the conduit and deforms vesicles and bands, (IV) the compaction of the pyroclastic domain due to the ascent of the plug, driving porosity reduction (to as little as 3% in the densest bands), with micro-folds and glassy fiamme, and (*V*) a final phase of post-sintering vesicle relaxation, yielding mainly rounded shapes. We compare our results with other exposed conduits to propose a model of conduit evolution during small-volume, short-lived silicic eruptions.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Talk

Investigating the ancient eruption histories of the pre-caldera Vitafumo and Miliscola monogenetic volcanoes (southwestern sector of Campi Flegrei, Italy)

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To assess the contribution of phreatomagmatism to the Campi Flegrei eruptive history, a detailed study of some monogenetic volcanoes was conducted. This research focuses on the stratigraphic analysis of the well-exposed, pre-caldera, ultra-proximal pyroclastic sequences from two distinct volcanoes: the Vitafumo and Miliscola tuff cones, located in the SW sector of Campi Flegrei volcanic field. The Vitafumo remnant comprises three main pyroclastic sequences, overall thick up to 130 m, separated by two erosional unconformities. The Miliscola succession, resting on a paleosol above the Vitafumo volcanic edifice, is up to 50 m thick. A dated tephra sequence above the Miliscola succession suggests a volcanic activity older than ca 70 ka for the two tuff cones. The Vitafumo and Miliscola sequences mainly consist of thick, poorly sorted, massive or diffuse stratified pumice lapilli deposits containing large blocks and scattered bombs, interbedded with massive or stratified, matrix-supported ash layers. Blackish and reddish stratified scoria beds are also present in the Vitafumo succession. This sequence is mainly unconsolidated but includes thick, lithified units and a thin welded horizon. A wide range of eruptive dynamics has been identified, including ballistic impacts associated with short-lived, buoyant eruptive columns accumulating pumice lapilli and blocks alternating with repeated column collapses emplacing unsteady and non-uniform pyroclastic density currents. Episodes of volcanic conduit erosion were also documented, along with intermittent phreatomagmatic pulses. The study revealed that phreatomagmatic phases, though present, are not dominant. Instead, they are interspersed with magmatic phases, probably resulting from significant destabilisation of the conduit-vent system.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Talk

Spectrum of magma sediment interactions intensity related to sediment properties and water confinement

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Magma sediment interactions occur at any interface between magma and sediment, including near-surface intrusions (0-500 m) or at the base of lava flows. The energy intensity of the interaction and the resulting contact shape are highly variable, and the interaction parameters are not well constrained. To understand the interaction parameters (calm through vigorous), 13 experiments using 7 different sediments, 15 to 30 l of remelted basalt, two water availabilities (confined and unconfined) and two different phases of water (liquidand solid) were run. The magma-dry sediment interactions form textures controlled by the heat transfer and the ability of the melt to move through the pore spaces. When magma interacts with wet highly porous and permeable material, the abundance of water does not affect the textures formed. However, when magmas interact with low porosity and permeability sediment, the water phase and availability affected the interaction. (1) Liquid water available between 0 to 11 vol % limits the interaction to baked sediment zones. (2) When the water available is liquid (unconfined), between 29 to 34 vol %, billowed textures and sediment trapped in the meltsediment interface are formed. (3) When the water available is 34 to > 40 % (liquid or solid) and confined, billowed textures, sediment is incorporated in the melt-sediment interface and top melt surface, and sediment paths through the melt can be formed. Detailed magma sediment interfacial textures in experiments resemble natural textures in 71 Gulch and Guffey Butte, suggesting that these experiments scale well to general magmasediment interactions.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Talk

Monogenetic, polycyclic, and polygenetic small-scale volcanoes in Central Mexico: examples of transitional eruptive styles

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A simple classification of volcanoes into monogenetic and polygenetic volcanic structures typically relates the former to small-volume, short-lived single eruptions (from days to several years) forming small-scale volcanoes and the latter to large-volume, long-lived eruption periods and large-scale volcanoes. However, numerous studies of small-scale volcanoes show complex eruptive behaviors, in some cases of a polygenetic nature and even transitional polycyclic eruptions, including multiple and complex eruptive phases of small volumes of magma separated by long periods (hundreds to thousands of years). Irrespective of the definition of these names, it is important to identify the role of each factor controlling the eruptive style, such as variations in magma flux, composition, water availability, vent migration, explosion depths, country-rock structure, and tectonic setting, which affect how magmatic or phreatomagmatic an eruption is and the volcanic structure it builds (scoria-cinder cones, tuff-rings, maars *sst*, domes, and combinations/complexes). We describe transitions between magmatic and phreatomagmatic eruptive styles observed in several Mexican small volcanoes (e.g. Alchichica, Joyuela, Cíntora, La Alberca basaltic maars), eruptions dominated by phreatomagmatic culminating with magmatic activity (e.g. Tepexitl basaltic maar), mixed and complex activity (e.g. Joya Honda, Aljojuca basaltic maars), magmatic activity producing polycyclic cones (e.g. El Volcancillo; Antofagasta cones), and rhyolitic volcanoes (e.g. Tepexitl tuff-ring), some showing polycyclic (e.g. Cerro Pinto tuff and dome complex) or polygenetic behavior (e.g. Cerro Pizarro dome). We discuss how the above factors affect the formation of small-scale volcanic landforms and their volcanic behavior.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Talk

Morphometric Analysis of Scoria Cones in Kula Volcanic Field (western Anatolia, Türkiye) Using Elliptic Fourier Descriptors and Fractal Dimension Metrics

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Scoria cone morphology provides insights into eruption mechanisms and post-depositional processes in monogenetic volcanic fields. While differences between cones can be identified using basic morphological parameters derived through conventional methods, determining the physical factors behind these variations remains complex. Recent contour-based studies have advanced the understanding of erosional processes and relative dating of cones shaped predominantly by hydrometeorological factors. This study uses Elliptic Fourier Descriptors (EFD) and Fractal Dimension (FD) metrics to analyze scoria cone erosion in the Kula Volcanic Field. Contours extracted from medium-resolution (~30 m) Digital Elevation Models (DEMs) of the selected cones were analysed to calculate Average Erosion Index (AEI) and FD values. Results indicate distinct erosion patterns across cones of different age groups. Older cones (β4; ~ 1-2 Ma) exhibit the highest AEI (22.9 ± 3.2) and FD (1.38 ± 0.01), reflecting prolonged effects of the surface modification processes on irregular/complex contour structures. Medial cones (β3; 50 – 300 ka) display moderate AEI (19.3 ± 3.1) with slightly lower FD (1.34 ± 0.01), likely stabilised by vegetation. Younger cones (β2; < 50 ka) have the lowest AEI (8 ± 2) but similar FD (1.35 ± 0.01) to medial cones, suggesting comparable primary volcanic or environmental processes. The findings highlight the potential usage of EFD and FD metrics for characterising erosional processes in scoria cones. Further studies using high-resolution DEMs and machine learning for predicting metrics and understanding the interrelations between different parameters are essential for refining these methods and exploring the regional impacts of climatic and hydrometeorological conditions.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Talk

Small-scale phreatomagmatic eruptions as precursors of larger caldera-forming eruptions: Insights from Acigöl caldera, Central Anatolia (Turkey)

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The Acigöl caldera (Cappadocian region, Turkey) offers a compelling case study of how small-scale, monogenetic-type eruptions, can initiate cascading volcanic processes culminating in large-scale, caldera-forming events. A detailed tephrostratigraphic analysis of a key outcrop within the Acigöl caldera, supported by glass chemistry and geochronological data, reveals a continuous sequence of volcanic deposits — including a debris avalanche, tephra ring, plinian fall, ignimbrite, and lava dome — indicative of rapid, successive eruptions without significant hiatuses. This study highlights how minor phreatomagmatic events, such the Taskesik maar, can serve as the initial trigger in a sequence of eruptions that ultimately lead to caldera roof collapse. This progression includes a Plinian phase along caldera ring fractures, which depressurizes the magma chamber and facilitates the subsidence of lithospheric blocks. Our findings underscore the importance of recognizing small-scale eruptions as potential precursors to major caldera-forming events, emphasizing their significance for improving hazard assessment strategies in active caldera systems, particularly those in densely populated areas such the turistic region of Cappadocia. This study has been funded by the the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Actions (PÜSKÜRÜM project, grant #101024337), and the Spanish Ministry of Science and Innovation under TURVO project PID2023-147255NB-I00, supported by MCIU, AEI (10.13039/501100011033), and FEDER, EU.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Talk

Constraints from source to surface: using Sr-Nd isotopes and olivine diffusion timescales in the Fui Group small eruptive centres (Chilean Andes)

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Small eruptive centres (SECs) located close to composite volcanoes are a common feature in the Southern Volcanic Zone of the Chilean Andes, and determining their level of connection is crucial to understand the magmatic processes in a small area comprising different styles of volcanism. Furthermore, determining the crustal pre-eruptive conditions and timescales can aid the assessment of volcanic hazards and describe the magmatic pathway for these SECs. The Fui Group Holocene SECs comprise two clusters: Fui Norte and Fui Sur, which are separated by less than 2 km and located next to the Mocho-Choshuenco volcano. Using Sr-Nd isotopes, we determined that Fui Norte cluster has an independent system, while Fui Sur would be genetically related to the Mocho-Choshuenco stratovolcano. Through mixing models, we determined that the isotopic signatures of Fui Norte are closer to a MORB mantle isotopic composition, whereas the Fui Sur cluster and Mocho-Choshuenco volcano have more influence of slab components. This result shows that even in very spatially constrained areas, magmas can show significant source differences. Using petrographic information and pre-eruptive conditions, we determined crustal timescales for the Fui Group, from 1-month up to 4.5 years. This unexpectedly large time-frame is interpreted to be the lifespan of the crustal reservoir for these SECs. The combination of chemical and petrographic approaches in the Fui Group show that the magma composition is controlled by the source composition, while the crystallisation history is associated to the crustal stalling and reservoir processes.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Talk

Small Domes, Big Picture: magmatic signatures across the slab tear in central Colombia

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Modern-day Colombia provides an active natural laboratory to better understand flat slab subduction. Here, geophysical surveys suggest the subducting Nazca plate is torn at ~5.5°N, with flat slab subduction north of the tear and classic, steeply dipping subduction to the south. We investigate small domes that postdate the Caldas tear to interrogate the tectonic and magmatic processes that led to their formation. We present whole-rock data, new mineral compositions and whole-rock isotopes (Sr, Nd, Pb) from three dome fields – with two domes to the north and six to the south of the tear. Overall, the domes have a calc-alkaline arc-like signature and are compositionally similar to modern polygenetic Colombian arc volcanism. The northern and southern domes are distinguished by mineralogy (amphibole ± biotite in the north; pyroxene in the south), mineral chemistry, and whole-rock isotopic signatures (higher $^{87}Sr/^{86}Sr$ and lower $^{208}Pb/^{206}Pb$ in the south), indicating differences in their origins north and south of the Caldas tear. Further, multiple plagioclase populations within single domes reveal complex histories of magma evolution even at individual domes. These geochemical similarities and differences between the domes allow us to contextualize them in the wider Colombian volcanic history. Together, their geochemical signatures point towards a difference in the petrologic origins of the northern and southern domes after the slab tear formed. On-going work aims to understand the P-T-H_2O conditions of magma formation and storage and details of the petrologic mechanisms that gave rise to these magmas.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Enigmatic transition of maar eruptions: A petrology and textural studies at Ranu Grati Maar, East Java, Indonesia

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Maar volcanoes represent an important yet often poorly understood archive of phreatomagmatic eruption dynamics. This integrated field, textural, petrographic, and geochemical study aimed to reconstruct the eruptive evolution and drivers of transitions at Ranu Grati Maar in East Java, Indonesia. Detailed stratigraphic logging of a ~15 m thick tephra succession exposed around the southern crater rim defined four tephra units (Unit 1 – 4) based on characteristic variations between brown-orange, brown-grayish, and black-grayish lithofacies. Grain size and component analyses revealed temporal shifts between dominantly juvenile black scoria phases (comprising 14-67% of the deposits), indicative of lower energy activity, and intervals of well-sorted tephra containing more evolved gray and golden (50-81%) scoria, suggestive of higher-intensity phreatomagmatic eruptions. Three distinct scoria types exhibit systematic mineralogical and compositional differences, with black scoria containing higher bulk crystallinities (average 44%) and mafic mineral assemblages (olivine ~2.4%), representing deeper and more mafic magmatic inputs. Geochemical trends between units suggest intermittent influxes of mafic and evolved magmas that modulate eruptive styles. Petrological and textural constraints indicate fluctuating pre-eruptive conditions in the shallow plumbing system, with recharge events triggering eruptive transitions between magmatic-dominant and phreatomagmatic activity over time. In summary, Ranu Grati's stratified deposits provide a record of cyclical maar behavior primarily driven by the coupling between recharging and evolving magma, with implications for volcano monitoring and hazard assessment.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Magma Depletion: A Swiss cheese alternative for vent distribution in volcanic fields

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For small volume eruptions, such as those common for volcanic fields, the location of an eruptive vent controls the hazards, their intensities, and ultimately the impact of the eruption. An eruption through water can result in a highly explosive phreatomagmatic eruption, as opposed to an eruption driven only by magmatic volatiles. We look here at long-term probabilistic assessments, the outputs of which inform evacuation plans, the (re)location of vital infrastructure, and inform the placement of early-warning monitoring equipment. Current estimates of future vent locations are based on point-process methods with probability surfaces built from spatial patterns, clusters, and/or lineaments identified from previous vent locations. These all assume that locations with more past-vents are more likely to produce future-vents. We provide here an alternative (but not necessarily better) hypothesis of magma depletion, i.e., that after an eruption, the magma source at depth is depleted in this area, causing holes or dips to appear in a probability surface. More formally: H_0: The location of future eruptions is inversely proportional to past vent locations. We present the maths, and code around how to produce various Swiss cheese estimates, and then set out to try and disprove our null hypothesis, all using the exemplar of the Auckland Volcanic Field, Aotearoa-New Zealand.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

InSAR observations and source model of a non-eruptive deformation event in 2019 at Lamongan Volcanic Field, Indonesia

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Many monogenetic fields are located in areas with high population densities. However, little is known about their unrest timelines. In the absence of ground monitoring, satellite data allows for monitoring of volcanic regions due to their large spatial coverage. Lamongan Volcanic Field (LVF), Indonesia consists of a stratovolcano which last erupted in 1898, and is surrounded by at least 90 monogenetic vents. We present InSAR measurements of non-eruptive ground deformation of ~12 cm towards and ~15 cm away from the satellite in 2019 detected by unsupervised machine learning algorithms at LVF. Deformation due to seismic slip is unlikely as there were no recorded earthquakes larger than Mw 3. Using improved techniques to process decorrelated InSAR data at highly vegetated areas and subsequent inversion for source parameters, we propose a deformation source model with two dikes: one 3.5-4.5 km long at ~ 3 km depth (opening: 0.3-0.9 m), and another 3–3.5 km long at ~2 km depth (opening: 1–2.5 m). Model residuals show that our uniform slip model broadly fits the deformation pattern. The 2019 intrusion could have been caused by the release of stress accumulated from a combination of a previous intrusion in 2007, local tectonics and topographic load. Recent unrest (deformation and seismicity) within the volcanic field highlights the possibility of new vents opening. This deformation event is an opportunity to study unrest mechanisms of a monogenetic volcanic field, which could be used to inform hazard assessments.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Arc scale distributions of small and large volcanoes: implications for magma supply

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Small volcanoes are by far the most numerous of volcanoes at continental arcs. Small volcanoes include scoria cones, maars, small domes, and small shield volcanoes. Most are monogenetic, meaning that they erupt once over a relatively short time. In contrast, large volcanoes, including composite and large shield volcanoes, account for most of the erupted volume at arcs. This study investigates the spatial and temporal patterns of eruption for several continental arcs. Preliminary results are based on extant data from the Cascades and the northern Central American Arc; work will be extending to the southern Central American Arc and possibly arcs in Chile and Japan. The morphology of all identifiable volcanoes along each arc was collected using a combination of manual analysis of maps, literature surveys, and digital analysis; satellite images and field interpretations guided the identification of volcanoes and classification into types. Summed eruptive volume and the number of vents for each segment along the arc vary significantly. The implications of the Castruccio model connecting magma chamber size, cone height, and basal radius are assessed on an arc scale. Where sufficient dating is available, all measures will be assessed for changes over time. The goal of this study is to understand how eruptive volumes vary along arcs, to investigate the implications of distributed volcanism within arcs, and to consider whether there are clues to magma chamber behavior in the morphology and size of volcanic edifices.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

In pursuit of intrusions and not hiding failed experiments

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Techniques leveraging liters of remelted basaltic rock to investigate volcanic phenomena have advanced rapidly in the last decade. A series of experiments at SUNY Buffalo established that force can be applied to molten basalt to create intrusive deposits in unconsolidated sediment. The reproducibility of these experiments was limited by continued exploration of apparatus improvements, but proof-of concept was established. These preliminary experimental intrusions provide valuable context for the scale of intrusive bodies in the presence of coolants (air, water, host substrate) and demonstrate aspects of heat transfer along complex geometries. Intrusions were created through gravitational forces on a lava static head in a pool by pushing rebar into the base to create intrusive pathways, or through a proto-type plunger device. These experiments produced mm to cm thick intrusive bodies that could extend up to 10 cm away from the outlet with convoluted geometries. Melt would travel into the sediment to the lowest pressure, which in many cases was up through the sediment pile or backwards towards the apparatus. These small intrusions produced concentric color changes in the host sediment. Sediment particles were also incorporated into the margins of intrusive bodies with larger (0.5 cm) particles reaching up to 1 cm away from the contact. As water content exceeded ~11 % by volume the intrusions failed by freezing in the apparatus conduit. Although logistics prohibited a full suite of intrusion experiments the samples and observations provide valuable inputs for interpreting natural deposits, numerical simulations, and potential future experimental designs.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Santa Clara scoria cone and its leaky plumbing system (southwest Utah, USA)

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Santa Clara volcano (~27 ka; Utah, USA) is a monogenetic volcano with a “leaky” plumbing system. Its products include a lava field (~0.1 km^3) and a scoria cone (~0.01 km^3). The ~145 m high (with respect to surroundings) cone was partially built on the shoulder of a ridge, and its crater floor is at a height of ~100 m. The ridge is elongated northeast-southwestward and consists of cross-bedded sandstone. Lava leaked from the western side of the ridge at a height of ~77 m and flowed downslope, forming a tabular-shaped, ~1.5-meter-thick outcrop. The steep slope favored lava acceleration and rupture of its surface, imparting ’a’a texture. On the eastern side of the ridge at a height of ~99 m, there is a 50 m long, 0.40-0.80 m thick sill which transitions laterally into a vent for partially welded agglomerates. Similar heights of the crater floor (~100 m), sill, and lava vent indicate concurrent vent activities under hydrostatic equilibrium during the latest eruptive stages. We propose a model where a vertical dike propagating beneath and parallel to the axis of the ridge, formed the main vent where the dike first intersected the surface low on the shoulder of the ridge. Magma continued rising as the cone grew until hydrostatic pressure equaled magma overpressure. There the magma spread into bedding planes to form a sill that leaked on both sides of the ridge. This model implies a magma overpressure between 1.1 and 2.8 MPa, consistent with overpressures estimated elsewhere for basaltic dikes.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Quantification of the phreatomagmatic-to-magmatic eruption style transition of a deeply eroded maar diatreme volcano applying high-resolution field and rock texture analysis

Mátyás Hencz*[a], Károly Németh[a,b,c], Tamás Spránitz[a], Tamás Biró[d], Dávid Karátson[d], Márta Berkesi[a]

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[b] *National Program for Earthquakes and Volcanoes, Geohazard Research Center, Saudi Geological Survey, Jeddah, Saudi Arabia* [c] *Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy* [d] *Department of Physical Geography, Institute of Geography and Earth Sciences, ELTE Eötvös Loránd University, Budapest, Hungary* Monogenetic volcanic fields provide critical insights into the complex interactions between magmatic processes, geological settings, and syn-and post-eruptive landscape evolution. This research focuses on the volcanic evolution of Szent György Hill, located within the monogenetic, phreatomagmatic Miocene-Pleistocene Bakony–Balaton Highland Volcanic Field in the Pannonian Basin, Central Europe. Szent György Hill represents a deeply-eroded monogenetic volcano. Field mapping and stratigraphic reconstruction based on mosaic-like outcrops revealed a complex volcanic architecture of the Szent György Hill. Image analysis of pyroclastic rock slab surfaces was used to quantify the relative abundance of different juvenile and lithic components within these pyroclastic samples correlated with their stratigraphy position. The analysis focused on distinguishing components resulted by phreatomagmatic (sideromelane glass) and magmatic (tachylite glass, basaltic clasts) fragmentation processes. The results suggest a temporal shift in eruption style at Szent György Hill from a relatively stable vent location. The initial phreatomagmatism is evidenced by the higher proportion of sideromelane glass in the lower stratigraphic units, which were driven by the interaction of rising magma and external water from syn-eruptive aquifers hosted in a combined Neogene siliciclastic successions and Mesozoic fracture and cavity-controlled, carbonate-dominated substrate. The spatially and temporally changing water supply is likely to have played a crucial role in the evolving eruption dynamics. The underlying siliciclastic sedimentary rocks and carbonate formations provided a combined, partially confined aquifer that influenced the amount and timing of water availability to fuel or suppress phreatomagmatism in the course of the evolving eruption.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Linking Small-Scale Textural Features to Large-Scale Volcanic Processes: A Study of Hell's Half Acre Lava Flow

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Lava flow eruptions from new vents in distributed volcanic fields can impact vast areas during relatively brief eruptions. Since these eruptions are rarely observed, observations of lava texture, overall flow structure, and models of emplacement processes provide crucial information to assess hazards and risks of these eruptions. The Holocene Hell's Half Acre eruption on the Eastern Snake River Plain (ID, USA), covers approximately 430 km^2. We conducted texture analysis, drone-borne LiDAR, mapping, and surface geophysical studies to better understand emplacement processes on one part of the lava flow. Quantitative measurements and qualitative descriptions were collected to characterize a unique surface texture we refer to as "lava lumps." These lumps, found in specific areas within the flow, were mapped utilizing the drone-borne LiDAR. A total of 309,152 m^2 was surveyed, enabling the generation of an elevation map that revealed a bimodal distribution of elevation across the flow. Further analysis led to the creation of a geological map highlighting the various structures present in this area of the flow. Supplemental electromagnetic data were gathered using ground-penetrating radar to measure lava flow thickness and investigate the internal structure at varying elevations. Our analysis of such a small area of the flow provided insights into larger-scale processes correlated with the eruption's complexity. The formation of the lumps and associated small-scale textures corresponds to the timing of lava rise deflation near the flow's northern edge. This larger-scale process initiated smaller-scale responses within the flow, giving rise to distinctive textural features unique to this phenomenon.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Origin, source and hazard of young intraplate volcanism in Saudi Arabia.

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Saudi Arabia hosts 13 small-scale intraplate volcanic fields, the so-called Harrats, covering a total area of ~90,000km^2. They are distributed along the western margin of the country at varying distances from the Red Sea spreading axis and the Afar mantle plume[1]. Magmatism of the Harrats began at ~30Ma, contemporaneous with the initiation of the Red Sea rifting, and has continued until historical times, with the most recent eruption in 1256AD, next to the holy city of Medinah[2,3]. The origin and source of the Harrats have been debated and are attributed to two endmember processes: 1) Upwelling of hot asthenospheric mantle from the Afar plume[4,5]; 2) Decompression melting caused by Red Sea extension and thinning of the lithosphere[6,7]. However, most studies investigated samples covering a large range of ages and thus may not be representative for the most recent volcanism. In this study, we focus on the youngest volcanic phase (<10,000ky) to assess the current origins, sources and hazards. We present whole rock major and trace elements, and radiogenic isotope data, along with mineral chemistry of the youngest volcanic products collected from 9 different Harrats throughout the country, to clarify why and how volcanism persists in this tectonically complex region and to evaluate the associated hazards of these small-scale volcanic fields. [1]Coleman et al.,1983,USGS Publications [2]Bosworth et al.,2016,Canadian Journal of EarthSciences [3]Downs et al.,2018,Geosphere [4]Bertrand et al.,2003,Chemical Geology [5]Lim et al.,2020,Journal of Geophysical Research:SolidEarth [6]Sanfilippo et al.,2019,Geological Setting, Paleoenvironment and Archaeology of the Red Sea [7]Sanfilippo et al.,2021,Frontiers in Earth Science

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Diverse Magmatic Processes and Eruptive Styles in the Serdán Oriental Basin : Insights from Mafic to Garnet-Bearing Rhyolitic Compositions

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Continental subduction zones exhibit diverse volcanoes and eruptive behaviors, influenced by complex and poorly understood crustal magmatic processes. The Trans-Mexican Volcanic Belt is an active continental arc dominated by monogenetic fields, but also punctuated by large polygenetic volcanoes. In the eastern region lies the Serdán Oriental Basin, which is characterized by abundant bimodal monogenetic volcanism ranging from the Pliocene to the Quaternary. At the center of the basin is the Las Derrumbadas Volcanic Field (<25 ka B.P.), where two large rhyolitic domes are surrounded by over a dozen monogenetic volcanic structures, distributed within a ~16 km radius. The basin is bordered by polygenetic volcanoes, such as Los Humeros. These volcanoes exhibit a wide range of eruptive styles and compositions, spanning from basalts to rhyolites with a dacitic gap, following a calc-alkaline series. Mafic and intermediate compositions represent small volumes (<1 km^3 per volcano), while rhyolitic magmas constitute larger ones (Las Derrumbadas domes >10 km^3). Two rhyolite groups distinguish: garnet-free and garnet-bearing. Mafic and intermediate samples show similar trace element spectra (LaN/YbN=5-13.6). Garnet-free rhyolites show relatively flat REE spectra (LaN/YbN=2), low REE concentrations, and a marked negative Eu anomaly (EuN/EuN*=0.08), attributed to plagioclase fractionation. Garnet-bearing rhyolites show slightly higher LREE content than mafic and intermediate compositions, but present a strong HREE depletion (LaN/YbN=49-201). We propose that mafic, intermediate, and garnet-free rhyolites are the result of polybaric fractional crystallization of mantle-derived melts, while the garnet-bearing rhyolites originate from the partial melting of mafic lower crust, followed by rapid ascension that preserves garnets.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Cenomanian Basalts on the Brazilian Equatorial Margin: Insights into Trigger Mechanisms of OIB-like Volcanism in Continental Environments

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Olivine basalts from the Serra do Cuó magmatism in the onshore Potiguar basin exhibit SiO_2 = 46-53 wt.%, MgO = 9-12 wt.%, and total alkalis = 3.5-6 wt.%, combined to elevated concentrations of large ion lithophile elements (Rb, Ba, Th, U, K), positive anomalies of Nb and Ta, and fractionated heavy rare earth elements. These lavas constitute a single volcanic event with evidence of fractional crystallization primarily involving olivine and pyroxene. Whole rock $^{40}Ar/^{39}Ar$ geochronology provided a minimum crystallization age of 99 ± 1 Ma, which is chronologically compatible with other Albian/Cenomanian igneous activity in NE Brazil. Clinopyroxene geothermobarometry indicates a range of crystallization depths from 23 km to 6 km, supporting crystal growth in a magma plumbing system before the emplacement. Radiogenic isotopes reveal enriched mantle-type, akin to Paleogene/Neogene alkali basalts elsewhere in NE Borborema Province. Rare earth element inverse modeling hints that Serra do Cuó melts originated at a mantle potential temperature of 1350°C, approximately 60 km depth. The long-lived alkali basaltic volcanism across the NE Borborema Province likely resulted from decompression melting of the mantle due to a combination of geodynamic factors, including episodes of hotspot influence and changes in South America's drift pattern.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Multidisciplinary insights into the Camp dels Ninots maar-diatreme: New geochronology identify the onset of the terrestrial Early Pliocene Warmth

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The Camp dels Ninots maar-diatreme in NE Spain represents a partially eroded tuff-ring volcano with lacustrine sediments in its crater that host an exceptionally preserved vertebrate fossil record. This maar-crater has been investigated through a multidisciplinary approach combining geophysical data, surface geology, and 11 boreholes reaching depths of up to 145 m. These efforts enabled the development of a 3D geological model of the

internal structure, providing new insights into the morphology of the diatreme and its facies distribution. The model reveals that the phreatomagmatic eruption occurred at a depth of ~210 m, coinciding with the intersection of a regional fault with the Paleozoic groundwater level. The resulting structure is a broad, funnel-shaped diatreme with shallow walls (30°–50°) and a smaller volume (0.004 km^3) compared to its tuff ring and lacustrine fill. These findings challenge existing deep, steep-walled diatreme models based on kimberlite pipes and clarify the relationship between phreatomagmatic deposits and subsequent lacustrine sedimentation. $^{40}Ar/^{39}Ar$ dating of juvenile pyroclastic rocks from a borehole has established the age of the volcano at 4.7 Ma. This precise volcanic age anchors the chronology of the Camp dels Ninots fossil site at 4.41 Ma, marking it as a unique reference locality for the Early Pliocene. The site provides critical insights into terrestrial ecosystems during this period, including the onset of the Early Pliocene Warmth, now dated in terrestrial Europe to 4.45 Ma. This exceptional record complements dominant oceanic data, addressing significant gaps in our understanding of Pliocene environmental and climatic transitions.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Groundmass crystallinities in the Auckland Volcanic Field as indicators of flow emplacement rates

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The Auckland Volcanic Field (AVF) includes 53 small basaltic cones that erupted from 193-0.55 ka [1]. With an increased frequency of activity over the last 60 ka around the city limits of Auckland (population, 1.7 million), activity in the AVF could be “in its infancy” [2]. Groundmass crystallinities from samples along the lengths of basaltic flow units from Rangitoto (504 ya [3], the youngest in the AVF, located 13 km from city center) and from Te Kōpuke/Mount St. John (75 ka [2], within Auckland city limits, and the longest flow in the AVF), are used to constrain groundmass crystal growth during lava flow emplacement. Distal samples in ’a ’ā flows from both volcanoes (2 km from the vent at Rangitoto [4] and 9.3 km from the vent at Mount St. John [4]) have groundmass plagioclase crystallinities that are more abundant, have larger crystal lengths and areas, and are blockier (lower aspect ratios) than in samples closer to the vents. Ongoing work will use cooling experiments to reproduce observed crystallinities to constrain the cooling rates of lavas as they were emplaced. Results can then be used to approximate the timing of emplacement, potentially for use by civil defense/emergency management in establishing evacuation protocols in planning for possible eruptive activity. [1] Hopkins et al., 2020; [2] Leonard et al., 2017; [3] Needham et al., 2011; [4] Rhodé, 2016

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Textural and compositional insights into magma ascent at Mount Gambier (Berrin) volcano in the active Newer Volcanics Province of Australia

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Australia hosts at least two continental basaltic volcanic provinces with Holocene eruption ages, yet little is understood about magma ascent and mantle to surface magmatic pathways and timescales in these regions. Such information advances our understanding of potential eruption warning timeframes of future volcanic activity. In this study we conducted mineral-scale textural and chemical investigation of a suite of stratigraphically constrained volcanic rocks from the Mount Gambier (Berrin) volcano. The ~5 ka maar-cone complex is the youngest volcano within the Newer Volcanics Province and mainland Australia and produced effusive magmatic to explosive (VEI 4) phreatomagmatic eruptions. The textural diversity and chemical zoning patterns in olivine and clinopyroxene in the volcanic rocks reveal a complex history of magma ascent. Olivine is classified into several types based on texture and composition: Normally zoned olivine at the margins of mantle xenoliths and rims of mantle-derived xenocrysts; skeletal, euhedral and polyhedral diffuse normally zoned autocrysts (dominant type); reversely zoned olivine; and olivine reaction rims on xenocrystic orthopyroxene. Olivine compositions and zoning (diffusion) profiles are used to map out the magmatic plumbing system and determine the timescales of magma ascent to the surface from distinct magmatic environments. The information gained from this work provides new insight into pre-eruptive magmatic history and magma ascent at Australian volcanoes. These results yield important implications for better preparedness to future volcanic hazards in Australia.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

The role of magma-flux on eruptive behaviour during the formation of the monogenetic Ubehebe volcanic centre, Death Valley, California.

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Phreatomagmatic eruption styles are often attributed to the presence or absence of water, but we propose that magma delivery rates play a greater role in controlling eruptive styles and fragmentation depths. Low magma flux or magma withdrawal favours subsurface phreatomagmatic explosions and cratering, while higher fluxes feed fountains and high plumes with widespread fallout. The Ubehebe crater cluster in Death Valley, USA, showcases how changes in magma supply shaped the weeks-to-months-long eruption from at least 14 vents ~ 2.1 ka. The eruption began with spattering and sporadic weak explosions along a N-S vent chain, ejecting large composite bombs (up to 2 m) along trend. As magma flux decreased, phreatomagmatic cratering formed the southern Amphitheatre Crater and emplaced surge deposits to the north. Renewed magma supply focused to the north, draining magma from the southern fissure and initiating phreatomagmatic explosions that extended the Amphitheatre northward, before driving violent strombolian activity that constructed a scoria cone and deposited fall material over ~93 km^2. Subsequent magma withdrawal renewed excavation of the Northern Amphitheater crater, truncating the scoria cone. Briefly increased magma supply then fed fire fountaining that formed the Little Hebe spatter cone. Later, E-W aligned craters formed orthogonally to the Amphitheatre craters. Overlapping deposits from these craters were capped by a ~9 km^2 fall deposit from Crater P, before formation of the Ubehebe Crater maar, the final and largest crater, as magma continued to withdraw. This study highlights how magma delivery, rather than surficial hydrological changes, governs eruption progression and magma-water interactions.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

A bigger tent for the Southeast Asian volcanic province

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The Southeast Asian volcanic province refers mainly to massive outpourings of basaltic magmas in southern Indochina and the Hainan Island over the Late Cenozoic, yet many small-scale volcanic fields scattering over Thailand and Vietnam might be related to the same magmatic system but remain poorly known and studied. In this work, we revisited the Dien Bien Phu volcanic field, and investigated another two volcanic fields, one at Thanh Hoa and the other at Lao Cai close to the Vietnam-China border, where no published data have yet been available. Representative $^{40}Ar/^{39}Ar$ dates of fresh, hand-picked matrix of volcanic rocks indicate eruption ages of ~510 ka (Thanh Hoa), ~5.6 Ma (Dien Bien Phu), and 418–442 ka (Lao Cai). The rocks display fractionated rare-earth element patterns without negative Nb-Ta-Ti anomaly, generally similar to OIB-like magmas. They have Sr-Nd isotopic compositions overlapping with the high-$^{87}Sr/^{86}Sr$, low-$^{143}Nd/^{144}Nd$ end of the array shown by basaltic rocks elsewhere in the Southeast Asian volcanic province. The new data confirm an earlier view that volcanism did not follow any systematic spatial-temporal patterns, and extend the known extent of the Southeast Asian volcanic province to ~22.7 ºN near the Vietnam-China border. Lastly, we address two competing models of magma genesis: localized lithospheric extension and passive upwelling of asthenosphere-derived melts, and active migration of plume-derived melts from the Hainan Island along trans-lithospheric structures such as the Red River Fault and related NW-SE-trending strike-slip faults.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Deep deformation of Tengchaong volcano zone and its east neighboring zone in the SE Tibetan plateau

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Tengchong volcano zone (TVZ) is in the SE margin of the Tibetan plateau, near to the east Himalaya tectonic knot. Its east neighboring zone is considered as the Sanjiang lateral collision zone between the India plate and the Eurasian plate, where is a crucial area for the study of the collision between the Paleotethys orogenic belt and the oblique subduction of the Neotethys. In order to studying the deep crustal deformation and low velocity mass movement in the middle-low crust, we adopted seismic data from three different temporary seismic arrays and regional permanent stations to obtain S wave velocity and azimuthal anisotropy in the depths from 3 km to 50 km. The results suggest that the low velocity (LV) materials from the Tibetan Plateau move generally southwards, with the fast velocity direction (FD) in N-S oriented. The geometry of the low velocity zone is along the Lijiang-Xiaojinhe fault (LXF) and the FD is influenced obviously by the LXF. The TVZ is at the west side of the LXF. In the south of Indochina block) and Baoshan block, near to the TVZ, the high velocity zone continues from the middle crust to the low crust. The FDs below TVZ shows NE oriented from 10 to 40 km. However the interesting is the low velocity body below TVZ seems to disconnect with the ascending material from the upper mantle, but is possible to connect to the LV materials from the Tibetan plateau in the middle crust. However, the further research is necessary.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Monogenetic volcanism and small volcanoes in the San Francisco volcanic field, Arizona, USA

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The San Francisco volcanic field, southwestern USA, hosts over 600 volcanoes within ~5000 km^2, ranging from small monogenetic cones to large composite volcanoes and in age from ca. 6 Ma to ca. 1085 CE. Government Prairie vent is a breached benmoreitic scoria cone and lava flow. A rhyolite dome fills the crater and dacite lava flowed from the cone's side. Xenoliths/crysts in the dome demonstrate magma mingling. An initial Strombolian event at Red Mountain was followed by partial cone collapse that included the vent area. Eruptive style changed to Hawaiian, producing extensive clastogenic lava. Post-eruptive phreatic explosions removed part of the unbreached side of the cone. Earliest deposits at Colton Crater are scoria and xenolith-bearing spatter. Phreatomagmatic explosions were caused by interaction of the feeder dike system with water, and caused collapse of part of the spatter rampart. SP Crater is a 'simple' Strombolian scoria cone with a lava flow that has bodies of vent-facies rocks, indicating rafting of the cone during eruption. Earliest phases produced spiky, vesicular tephra and poorly vesicular tephra was deposited after breaching as the cone rebuilt. A second lava flow filled in lower areas of the original flow. Strawberry Crater is a breached cone. Three lava flows and facies within the cone document rafting and destabilization of the crater walls as well as changes in chemistry. A trachydacite dome was emplaced in the latest stages. Cones in the field illustrate some of the many forms of eruptions and hazards possible in a mafic monogenetic system.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Neogen volcanism in the NE Iberian Peninsula: Magmatic systems, origin and evolution (NEOVOLC project)

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The Catalan Volcanic Zone (CVZ), located in the northeast of the Iberian Peninsula, is an intraplate monogenetic volcanic field in the region of interaction between the opening of the Western Mediterranean and the European Rift System. Despite being a key area for understanding the interrelation between magmatism and tectonics in monogenetic volcanic systems, fundamental questions remain unanswered: What processes control magma's ascent and its stagnation in depth? How have the magmatic systems in the region evolved over time? How are these processes connected to the opening of the Western Mediterranean and the European Rift System? The NEOVOLC project addresses these questions through a multidisciplinary approach that integrates petrology and geochemistry of magmas, geochronology of the erupted volcanic products and structural data. Special attention is conferred to the interaction between the magmatic system and regional tectonics to understand its influence on the eruptive style and frequency of eruptions. The results will contribute to advancing the understanding of the volcanism of the CVZ and its global implications in other intraplate volcanic zones. In addition, they will provide key information to properly assess the volcanic hazard of the area and support the risk management of this active volcanic zone.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Lithofacies architecture of andesitic-rhyolitic lava dome complex: insights into multiple growth and submarine-subaerial transition, Som Hill, Tokaj Mts, Carpathian-Pannonian region

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Well-preserved examples of volcanic formations comprising submarine to subaerial emergences are rare in the geological record. The present work explores the volcano-sedimentary stratigraphy of Som Hill succession (>200m), which composed of a Miocene (12.4-11.2 Ma) andesitic-rhyolitic effusives interbedded with sedimentary and pyroclastic deposits. Aiming this, over 100 boreholes were revised. Additional fieldwork was conducted on the active quarry and surface exposures. Effusive lithofacies comprises rhyolite and andesite lavas, consisting of an inner coherent core that grades outward into clast supported breccias (autoclastic, hyaloclastite and peperite). Volcano-sedimentary lithofacies comprise pyroclastic deposits including diverse lapilli tuffs with varying lithic enrichment, secondary volcaniclastic deposits including monomictic breccias and tuff-matrix breccias, volcanogenic sandstones and mudstones. Together, these lithofacies describes (1) submarine andesitic lava domes and flows (2) volcaniclastic - sedimentary units (3) submarine rhyolitic cryptodomes (4) pyroclastic deposits and (5) subaerial andesitic-rhyolitic domes and flows. During the eruptive period, two significant effusive events took place with a similar cyclic pattern. The initial effusive activity was characterized by andesitic composition followed by emplacement of silicic lavas. This pattern suggests that magma batches of varying compositions were being excavated. Sedimentation occurred before and at the onset of the volcanism, while explosive products were deposited after the initial cycle. The change in the fragmentation style of the lavas towards the top of the succession, along with the pyroclastic deposits, indicates a transition from shallow submarine to subaerial environment. **Acknowledgements.** Funds.

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Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Accretionary lava balls record the Pāhoehoe to `A` ā transition

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Mafic lavas are a widespread product of effusive volcanism. They commonly erupt as pāhoehoe lava and transition to aā as they travel from the vent. Pāhoehoe lavas have a smooth, near continuous surface and are capable of engulfing large areas. While aā lavas have a surface crust that is fragmented and rough; they also can self-channelise, form levees, and overturn structures. These vastly different surface morphologies also give rise to different thermal characteristics, where aā with a disrupted crust exhibits greater heat loss. Thus, determining when different lava flow morphologies form and the physical processes behind morphological transitions is important for hazard mapping and lava flow modelling. Here, we present a series of detailed field observations and laboratory analyses on accretionary lava balls that formed at, or very close to, the pāhoehoe to aā transition. The lava balls were spatially mapped belonging to the most recent effusive products from Tseax (*Sii Aks*) volcano, British Columbia, Canada. They have a low-density, vesicular core comprised of pieces of pāhoehoe crust and are coated by multiple thin layers of denser, microlite-rich, poorly vesicular lava. We discuss the physics behind their formation and how they can be used during field studies on mafic volcanoes to infer lava flow dynamics, especially the transition between pāhoehoe and aā lava flow morphologies.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Assembling the architecture of basaltic discrete explosions and lava fountains

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Weak basaltic explosive eruptions are highly dynamic and prone to rapid spatial and temporal transitions in style and intensity. They occur in almost any kind of volcanic setting, including persistent volcanoes, stratovolcanoes, shield volcanoes, calderas, and monogenetic volcanic fields. Many eruptions are classified as either discrete explosions (time scales seconds-to-10's of s) or prolonged events (duration typically hours to weeks). Prolonged events (lava fountains) can be separated into episodic vs sustained and into steady vs unsteady. Transitions between discrete explosions and fountains are common: In particular, many lava fountains begin or end with intervals of weak discrete explosions. We suggest a framework for describing these events using a three-tier hierarchy: - pulses are the fundamental subunit for these eruptions. Durations are typically sub-sec or sec. - events are the characteristic units for Strombolian (explosions) and lava fountain (episodes) - eruptions are widely spaced collections of related events. This standardizes descriptions of basaltic explosive activity across different volcanic settings and temporal scales, and enables consistent comparison of eruption dynamics between volcanoes and better communication of hazard scenarios among researchers and monitoring agencies. The nested structure reflects a natural organization of these eruptions in a common vocabulary that bridges field observations, monitoring data, and physical models.

Theme: 3. Volcanic processes

Session 3.7: Small-scale volcanoes and their large-scale volcanic context

Allocated presentation: Poster

Holocene monogenetic silicic phreatomagmatic volcanism on the Altiplano of Bolivia: Cerro Volcán Quemado

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The global record of significant volcanic eruptions is incomplete, limiting our understanding of volcanic history. One surprising unrecorded example is Cerro Volcán Quemado (CVQ), a rhyolitic monogenetic tuff cone-dome volcano located on the Altiplano behind the Central Volcanic Zone (CVZ) arc, a region dominated by effusive andesitic composite cones. Although CVQ is undated, its morphology suggests a Holocene age. Archeological evidence indicates that pre-Hispanic communities lived near CVQ but suddenly disappeared, raising the possibility that an eruption contributed to their disappearance. CVQ may hold critical insights into recent volcanic history and potential hazards in the Altiplano. CVQ's magmas are bimodal, with one extreme being rhyolite and the other being basaltic andesite, distinguishing it from the region's typical andesitic to dacitic compositions. Trachyandesites exhibit high Sr/Y ratios (84 to 90 ppm) indicating a deep crustal source, and amphibole thermobarometry indicates polybaric evolution in the mid-crust. In contrast, rhyolites have low Sr/Y values (13 to 20 ppm) indicating a shallow crustal source. CVQ's $^{206}Pb/^{204}Pb$ (~18.0) and $^{207}Pb/^{204}Pb$ (~15.6) isotopic signatures align with basement compositions indicating significant crustal contamination. $^{87}Sr/^{86}Sr$ isotopes (~ 0.706) show no correlation with differentiation. Our interpretation is the magma of CVQ originated in the deep crust through assimilation of the Arequipa-Barroso basement by mantle-derived basaltic magma and polybaric crystal fractionation produced trachyandesites and then rhyolites as the magmatic system traversed the crust. The phreatomagmatic character of the eruption connotes a recent wet period on the Altiplano.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Talk [Invited]

Volcanic hydrothermal systems on andesitic composite volcanoes – Mineralogy, 3D architecture and their use to understand flank collapse activity

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Volcanic hydrothermal systems are common to many andesitic composite volcanoes, yet their evolution, mineralogy, and significance often remain underexplored. This study highlights new approaches to understand the evolution of composite volcanoes by leveraging insights gained from geological mapping of hydrothermally altered deposits. We applied extensive field work and sampling, combined Scanning Electron Microscopy, Shortwave Infrared reflectance spectroscopy, X-Ray Diffraction, stable isotope systematics, X-Ray Fluorescence, thermodynamic modelling, airborne and close-range hyperspectral imaging and aeromagnetic surveys. Using Ruapehu (New Zealand) as a case study, we demonstrate how such analyses can provide critical information for improving volcanic hazard assessments. Our research examines fossil and active hydrothermal systems exposed in the southern sector of Ruapehu that show a diverse suite of weathering and hydrothermal mineralogy formed since 160 ky. Most of these are located with the Wahianoa Formation (160-80 ky), ranging from deeper phyllic- (>220 °C and more neutral pH) to shallower argillic alteration zones (80-200°C and low pH). This transition reflects variations in fluid temperature and pH within the exposed fossil hydrothermal system. Additionally, the outcrops reveal a complete lateral progression, from core alteration zones to more distal regions characterized by intermediate argillic and supergene alterations, featuring abundant goethite/hematite, and phyllosilicate mineral assemblages. We found a complex interplay between volcano growth/evolution and hydrothermal alteration history. A new model has been proposed to integrate hydrothermal alteration history into the Mt Ruapehu's evolution that can better depict ongoing alteration processes and triggers for flank instability and volcanic hazards associated with hydrothermal systems.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Talk

Investigating the influence of Deccan Volcanism and hydrothermal alteration on seismic hazards in the Koyna-Warna Seismogenic Region, Western India

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The Koyna-Warna Seismogenic Region over the Deccan Volcanic Province (DVP) in Western India has experienced >1,00,000 low-magnitude earthquakes during the last six decades soon after the Koyna Dam's impoundment. The Seismogenic faults in this region are N-S oriented indicating their generation due to the Deccan volcanism and Western Ghats upliftment rather than Indo-Eurasian Collision. Hence, apart from the plate boundary stress transferred through fault interaction and hydrostatic stress due to reservoir water, the stress concentration resulting from the high-density magma intrusion can't be ruled out. The scientific drilling unravelling the thicker basaltic sequences over the basement rocks in the central part of this area relative to other segments confirms the role of Deccan volcanism in stress accumulation in the shallow crustal faults. The mineralogical studies on the core samples from these faults upto 3 km depth find the transformation of biotite into chlorite and epidote, plagioclase into illite and albite as well as precipitation of calcite. The geochemical analyses additionally answer how the porous and vesicular Deccan lava sequences acted as the fluid percolation pathways and resulted in propylitic hydrothermal alteration. Further, this study demonstrates that the strength of the hydrogen bond connecting the talc-like layers with brucite-like sheet in the hydrothermally produced chlorite may help to accommodate strain in its crystal through ripplocations and result in fault creep responsible for the recurrence of low-magnitude quakes. This hypothesis also explains how hydrothermal alteration in this part of DVP gave rise to rheological heterogeneity suitable for Type-2 earthquakes of Mogi's Model.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Talk

A finding of vapor-dominated zones within the caprock beneath the major fumarolic manifestations and its implications; CSAMT survey of fumarole area in Hakone volcano, Japan

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Monitoring fumarolic areas is essential for detecting volcanic unrest and predicting phreatic eruptions, but interpreting the signals obtained requires understanding the underground structure. We implemented a CSAMT survey in Owakudani, the largest fumarole field on Hakone volcano, Japan. The caprock detected as a low-resistivity zone forms a plateau-like convexity with a diameter of approximately 500 m. The ground surface above the caprock top forms a forested area with patchy steaming areas, contrasting with the barren 2015 hydrothermal eruption center east of the region. The caprock top had subsided before the 2015 eruption, possibly because of the depressurization beneath the caprock. Interestingly, the caprock has local yet distinctive high-resistivity zones, particularly beneath major fumaroles and hot springs. These local high-resistivities and beneath the caprock are interpreted as vapor-dominated. Previous studies indicate that meteoritic water heated by steam from the vapor-dominated hydrothermal system forms hot springs in the fumarole area. However, our chemical analysis indicates that merely mixing the meteoritic water with the steam beneath the caprock of Owakudani, which is high-Cl and acidic, cannot produce surface hot spring waters there. The two vapor-dominated zones beneath the major hydrothermal manifestations likely differentiate the hydrothermal fluid.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Talk

Impact of hydrothermal activity on the geomorphology of the Nisyros intra-caldera region

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Hydrothermal activity and alteration can lead to mechanical weakening of volcanic rocks, decreased edifice stability, or increased erosion. Reversely, weakened zones such as faults can lead to localized hydrothermal alteration effects, so that a two-way interaction may be evident. A better understanding of these processes and interactions is particularly important in volcanic island environments due to the potential risk of slope failure and tsunami generation. To better investigate this, we analyze the hydrothermal system of Nisyros aiming to discriminate the relations between local faulting and the shallow hydrothermal system and to quantify the impact of the hydrothermal activity. We find that present hydrothermal eruptive centers indicate an interplay between shallow hydrothermal aquifers and fault orientations. Aligned sinkholes in the Lofos-Polivotis-Flegethron Complex (LPFC) indicate enhanced alteration and subsurface erosion over buried fault segments. Aligned sediment expulsion sites and vent-like deformation structures indicate liquefaction processes along the fault trends. Also in the main explosion crater wall (Stefanos crater) we find indications for local fault slip, oriented in azimuth of the main tectonic trend (NE-SW). However, a rotation of the main surface ruptures of the 2001 earthquakes within the Lakki plain and alignments of small-scale features perpendicular to the tectonic trend suggest additional importance of intersecting faults on the activity pattern. An unstable flank appears to be controlled by the mutual effects of local faulting and hydrothermal activity. We combine our observations and give an overview of the dynamics and impact of the hydrothermal system in the intra-caldera region of Nisyros.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Talk

Continuous subaerial mapping of hydrothermal outflow in Milos: the new view from visible and infrared drone imaging.

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Milos is an island of the Aegean volcanic arc developed during plio-quaternary transtensive tectonics. The island displays ground deformation, seismic activity, historical phreatic explosions and is the most important high-enthalpy geothermal field in Greece (Liakopoulos 1987; Fytikas 1989). The area contains indications of hydrothermal activity, including gas and liquid emissions (onshore: altered soils, local mineralization, hot soils and fumarolic vents; offshore: bubbling vents, bacterial mats and precipitates). To characterize the subaerial and underwater near-shore hydrothermal circulations in space we conducted an extensive aerial drone survey from Kalamos headland to Agia Kyriaki and Psaravolada bays, acquiring visible and infrared (IR) photomosaics. Regional qualitative T°C maps were obtained, corrected using landmarks of known emissivity. IR images highlight the morphologies of T°C anomalies, that correspond to diffuse, localized, elongated, circular zones of activity, and that have been correlated with geological features (e.g. fault-zone, fault-rocks, fractures, silification and argilitization). At the metric-scale, we document both local T°C gradients and highly localized T°C anomalies . At regional-scale, thermal anomalies generally strike either N-S (Zephyria graben orientation) or NW-SE until the Agia Kyriaki bay (Fyriplaka graben orientation). NE-SW orientations are also visible (Main Cycladic Lineament, see Cavailhes et al., 2025). Our modern, multi-scale, multi-methods and integrated mapping defines an heterogeneous regional thermal scheme which is tectonically-controlled, i.e. where preferential hydrothermal pathways and zones of potential hydrothermal fluid accumulation have been characterized. References -Cavailhes et al., 2025 “IAVCEI25-abstract” -Fytikas 1989, doi:10.1016/0375-6505(89)90060-6 -Liakopoulos 1987, Univ.-Paris-6 Thesis Researchgate.net -weblink

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Talk

Combining 3D ERT, drone and satellite images with geochemical analysis to investigate the nature of the Goshogake hydrothermal field, Japan.

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The western flank of the Akita Yakeyama Volcano (Tokoku, Japan), hosts the Goshogake hydrothermal system. Interestingly, Goshogake lies between the magmatic volcanic arc and the sedimentary hydrocarbon-rich backarc of Japan. Goshogake features a large variety of surface manifestations with temperatures ranging from 33 to 97 °C along with acidic pH values of approximately 2.5. The hydrothermal emissions emerge at the base of a narrow valley, where a N-S fault system framing the Akita Yakeyama volcano is suggested to occur. We conducted a 3D Deep Electrical Resistivity Tomography, combined with drone-derived thermal photogrammetry and satellite images. A total of 25 Iris Fullwavers were deployed to acquire electrical resistivity data across the Goshogake hydrothermal field. The inverted resistivity model shows a conductive system enabling differentiation of the conduits feeding the vents. Data were compared with geochemical analyses which indicate that the active sites are H2S- and CO2-dominated with a clear mantle-derived isotopic signature. In contrast, colder seepage sites reveal the presence of minor quantities of methane, although its origin (either thermogenic or abiotic) remains unsolved. Ongoing analyses conducted on the inferred oil films will allow to distinguish its origin. Potential scenarios include a) the presence of shallow oil derived from the alteration of recent organic-rich deposits, or b) deep oil originating from the thermo-methamorphism of deep seated lacustrine deposits hosting the volcanic complex. If the second scenario is validated, Goshogake could well be Japan's first known example of a sedimentary-hosted geothermal system considerably increasing regions suited for geothermal potential.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Talk

Investigating the thermal evolution of Surtsey using HYDROTHERM numerical simulations

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Surtsey, a volcanic island off Iceland's south coast, was created during a series of eruptions from 1963 to 1967. In 1979, a cored borehole was drilled through the eastern crater, providing structural and stratigraphic insights into the young subaerial and submarine basaltic deposits. Regular downhole temperature measurements provide a time-series of temperature data spanning decades. As part of the ICDP SUSTAIN project, three new cored boreholes were drilled in 2017. These include two vertical drillholes, measuring 152 m and 181 m, and a 354 m inclined drillhole that reached ~100 m below the pre-eruption seafloor, confirming the presence of a deep eruptive conduit excavated through seafloor sedimentary rocks. Borehole measurements from 2018 show maximum temperatures of more than 120°C within the vertical drillholes and ~60°C within the eruptive conduit, ~50 years post-eruption. The borehole measurements present a unique opportunity to investigate the island's cooling history using numerical modelling, constrained by laboratory material property measurements on 2017 drill cores. This research uses HYDROTHERM simulations to evaluate the thermal contributions of residual heat from erupted materials and magmatic intrusions to Surtsey's thermal budget and to assess the effects of structural features within the island on cooling. The results indicate that heating from syn-eruptive intrusions can only account for a minor part of the post-eruptive thermal state. A large part of the island is capped by a lava shield which may have played a significant role in reducing heat loss. Exothermal alteration processes associated with seawater fluid-basalt interactions may have enhanced geothermal activity.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Talk

Metals in tuffisite veins

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Fractures are the main outgassing pathway of shallow felsic magma. Diffusion profiles of hydrogen around tuffisite veins, hydrofractures occluded with sintered pyroclastic material, suggest lifespans of such pathways of minutes to hours. Diffusion of other elements, e.g. Li, Na, Rb, has also been observed. This mobility of elements, particularly H, affects crystallisation, which in turn promotes further element redistribution. Tuffisite veins are not only sites of outgassing, but form transient, permeable networks in the shallow conduit through which the MVP and particulates are transported from deeper magma. Elements are redistributed between MVP, host and vein-filling material. This study takes a look at this redistribution of elements during MVP advection and clast-MVP interaction. Three tuffisite veins from the 2008-2011 eruption of Chaitén volcano in Chile with similar appearance were selected for tandem LIBS-ICP-MS analysis and element mapping. In each vein, similar components were identified: host, angular clasts, vesicular clasts, microcrystalline clasts, and the matrix of sintered ash. The matrix and the microcrystalline clasts in all three veins are consistently depleted in major- and incompatible trace-elements. They are however enriched in volatile metals, which can be traced to individual phases, though the degree of enrichment and the specific metals involved differ between the veins. These differences between the veins may result from their formation at different depths as they have different H and Cl concentrations. Multivariate analysis suggests that the depletion in most and enrichment in some elements are the result of a single process of mobilization and redistribution of elements.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Hydrothermal alteration and multi-phase 3D structure of the summit of La Soufrière de Guadeloupe

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Hydrothermal alteration plays a major role in volcanic instability. Thus, improving techniques that allow us to better understand the processes and timescales of alteration in active volcanoes is paramount. Since the reactivation of the fumarolic field at the top of the dome of La Soufrière de Guadeloupe (Guadeloupe, France) in 1992, and its expansion in recent years, the top of the dome has been subjected to prolonged and variable alteration. Such alteration has promoted past flank collapses and can also influence permeability and thus subsurface overpressurization. During a field campaign in May 2022, we performed 25 electrical resistivity tomography (ERT) profiles on the summit of La Soufrière, next to active fumaroles and acid boiling ponds. These ERT profiles were inverted together using the open-source code E4D. From field studies, we have identified clays, sulfates and pyrites which are all byproducts of alteration. Thus, we infer that high electrical conductivity zones (>1 Sm-1) correspond to alteration and areas fully saturated with acid brines, and that low electrical conductivity zones (<0.001 Sm-1) correspond to unaltered rock or gas filled pockets. We account for ground temperature and spatial variability to interpret the electrical conductivity anomalies, and we use this first high-resolution 3D conductivity map as the first step in a time-lapse inversion of the surveyed area.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Cristobalite Formation in Synthetic Glasses through the Role of Mineralizing Agents in Alteration Experiments

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Cristobalite, a silica (SiO_2) polymorph often observed in volcanic systems, forms from vapor precipitation and glass devitrification at conditions outside of its stability field. Here we study the role of mineralizing agents (Al, Na, and K) in promoting metastable cristobalite formation at temperatures below its thermodynamically stable state. To do this, we synthesize four rhyolitic glasses, controlling for Al, Na, and K content. These glasses are then powdered to grain sizes of 60-90 microns and altered in externally heated, closed system, stainless steel pressure vessels at 200°C and water vapor pressures of 1.5 MPa over 1 to 8 weeks, using acidic and alkaline fluids. This allows us to simulate rock-fluid interactions under relevant volcanic dome conditions. Preliminary post-experiment solid (XRD) and fluid (ICP-OES) geochemistry indicate that tridymite nuclei present in the initial glass were partially or completely transformed into cristobalite after four weeks, under alkaline fluid conditions. These preliminary results suggest a possible relationship between tridymite presence and cristobalite formation in volcanic glasses and highlight the efficiency of alkaline solutions for the dissolution, mobility, and local redistribution of silica. Future work is needed to quantify 1) the concentration of mineralizing agents in these silica polymorphs and 2) how these mineralizing agents drive polymorph formation outside of their stability fields.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Reactive Flow-Induced Alteration and Permeability Evolution in Volcanic Rock Analogues

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The dynamics of volcanic systems are partly governed by rock-fluid interactions, with chemical reactions altering fluid flow pathways, modifying the physical properties of these rocks. Changes in permeability and porosity may eventually result in the sealing of fluid pathways, increasing the propensity to explosive behaviour. We assess how alteration affects sample microstructure and permeability. To do this, we use the novel High temperAture Reactive flOw permeabiLity Device (HAROLD) to perform *in-situ* flow-through experiments at temperatures up to 500 °C and an effective confining pressure of 30 MPa. We alter structurally simple volcanic rock analogues - sintered soda-lime glass bead samples with porosities ranging from 0.05 to 0.25 - with reactive fluids enriched in silica or calcite. Steady-state permeability is monitored over time as reactive fluids circulate and alter the microstructural properties of the samples. Pore fluid is sampled before and after interaction with the sample, and fluid chemistry is used to determine the timescales of reactions. We use micro-computed tomography (μCT) to image pre- and post-experiment microstructure, allowing for precise quantifying of the geometry of alteration. Our findings will be used to provide critical insights into the role of permeability changes in fluid flow in volcanic systems.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

From Cause to Hazard: Assessing Alteration-Induced Instability in Volcanic Domes

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Volcanic domes are unstable structures due to their incremental growth, varying extrusion rates, and diverse material properties. Domes frequently collapse due to factors such as hydrothermal alteration. Hydrothermal fluids interact with volcanic rocks, altering their physical and chemical properties and often results in mechanical weakening. Thus, domes commonly collapse and generate turbulent avalanches of material, threatening communities and influencing the volcano's eruptive dynamics. The internal structure of the La Soufrière de Guadeloupe dome has been mapped using geophysical methods to obtain rock density variation within the dome. Density contrasts were correlated with mechanical parameters to obtain a 3D strength map of the volcano. We input this data into large-scale 3D models that employ the Discrete Element Method. Scenario testing evaluates how changes in the location, intensity, and extent of alteration affect dome stability. We calculate alteration-induced displacement and strain, and therefore suggest the potential for large-scale collapse given varied alteration scenarios. More pervasive alteration (weakening rock to 10% of its original strength) and broader spatial extent (150 m thick zone over the southern flank) leads to larger collapse volumes. We compare these results with alteration scenario testing for a homogeneous model, i.e. if geophysical data were unavailable. Models with material heterogeneity result in displacements an average of 53 times their homogeneous counterpart. at a 10 cm threshold, and further compromise dome stability. We input our results into 'VolcFlow' to estimate collapse runout distances and discuss the severity of alteration-induced collapse hazard for the island of Guadeloupe to mitigate future risk.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Mechanical implications of a hydrothermal core within Teide volcano, Tenerife

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Tenerife (Canary Islands) has undergone several north-directed lateral collapses. Previous studies have suggested that the active stratovolcano Teide in central Tenerife continues to exhibit potential flank instability to the north related to ongoing volcano spreading, which is thought to accelerate during magmatic and hydrothermal episodes. While outward displacement commensurate with spreading is not observed, morphological and structural features have still been linked to possible spreading. The volcano shows a concave slope profile on the northern flank, as well as normal faulting at the summit. These features may imply (1) a gently dipping low-strength breccia layer at the base of the volcano, facilitating large-scale spreading; and (2) the presence of a hydrothermally altered core and crater area later overgrown by the edifice. Here, we test these ideas using a combination of high-resolution drone imagery, rock mechanics testing, and computational modelling. We test rock samples from the (1) pre-medieval Teide cone (Old Teide); (2) Old Teide's crater rim; (3) Teide's new summit cone; and (4) lava that descended downslope from Teide's most recent summit eruption (Lavas Negras) and quantify the physical and mechanical properties for the different stratigraphic units. We then perform simple finite element method modelling that incorporates these rock properties for a simplified stratigraphy and incorporates a hydrothermally weakened core. We investigate whether the observed slope concavity can be reproduced considering only mechanical weakening from an altered core.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Using multispectral satellite data and cloud computing to monitor hydeothermal alteration in Lastarria Volcano

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Hydrothermal alteration refers to the interaction between hydrothermal fluids and host rocks. In active volcanoes, the main components of hydrothermally altered rocks could be varied with different intensities of hydrothermal systems, while remote sensing tools can capture the surface manifestation of these rocks. Herein, we review the commonly used remote sensing methodologies and provide a new Hydrothermal Deposit Index (HDI) to achieve long-term monitoring. Lastarria Volcano, located at the center of the Andes volcano belts, was selected as the case study, benefiting from its frequent degassing and a larger area of hydrothermal deposits. We tracked the HDI variation of the main hydrothermal alteration zones during the periods of two newly developed sulfur flows and indicated the dependency relationships. In addition, we demonstrated the HDI increase in the summit crater area accompanied by the obvious expansion of hydrothermal alteration zones prior to the sulfur flow development. Therefore, we considered the surface hydrothermal activity anomalies starting from the summit crater and progressing down to the flank area. The high-intensity hydrothermal energy could significantly enlarge the hydrothermal alteration zones in the summit, while residual energy may vary local fumarole activity and trigger the development of sulfur flows in the flank area.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Hydrothermal sealing and erratic explosive behaviour at Rincón de la Vieja, Turrialba, and Poás volcanoes (Costa Rica)

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Reductions to the permeability of a volcanic system can increase pore fluid pressure and, in turn, promote volcanic hazards. Hydrothermal alteration, ubiquitous at volcanoes worldwide, is one mechanism thought to reduce permeability and therefore increase volcanic hazard potential. Turrialba, Poás, and Rincón de Vieja, active stratovolcanoes in Costa Rica, are characterised by challenging-to-forecast phreatic and phreatomagmatic eruptions that are thought to be the result of the formation, maturation, and rupture of hydrothermal seals that clog the conduit. To better understand this process, we present here a systematic study in which we assessed the textural, mineralogical, and physical properties of hydrothermal seals from Turrialba, Poás, and Rincon de Vieja volcanoes, ejected as ballistics following recent explosive activity. We first documented the type and intensity of the hydrothermal alteration preserved in the collected ballistics using scanning electron microscopy and X-ray powder diffraction. We then measured their porosity, permeability, specific surface area, and tensile strength. We found that, despite their typically high porosities, the materials forming the hydrothermal seal are characterised by low values of permeability (as low as 10^{-18} m^2). Microstructural observations show that this low-permeability is due to pervasive hydrothermal alteration. Numerical modelling using COMSOL Multiphysics shows that permeability reductions resulting from hydrothermal alteration are capable of generating pore pressures beneath the hydrothermal seal that exceed the tensile strength of the materials forming the seal. Our laboratory data and modelling, therefore, highlight how hydrothermal alteration can create a low-permeability hydrothermal seal that promotes cyclic, but erratic, explosive volcanic behaviour.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Hyperspectral imaging, mineralogy, and outgassing, exploring the volcanic hydrothermal system of Red Crater, Tongariro, Aotearoa / New Zealand

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Volcanic flank collapse and phreatic (steam driven) eruptions pose considerable proximal and distal hazards, while being notoriously difficult to forecast. Such phenomena are associated with hydrothermal activity, where hot, acidic subsurface fluids circulate through and alter the rock beneath the surface. This process of hydrothermal alteration may reduce rock strength and cause landslides (Tongariro, 2012), as well as seal degassing pathways, which may generate overpressure in the system and cause a phreatic eruption (Whakaari/White Island, 2019). Hyperspectral remote sensing presents a unique opportunity to explore both the outgassing and alteration associated with these hydrothermal systems, whereby diagnostic spectral signatures in the VNIR (400–1000 nm) and SWIR (930–2500 nm) regions of the electromagnetic spectrum are used for mapping common alteration minerals and carbon dioxide detection. We combine remote sensing (lab/airborne hyperspectral, thermal infrared), field (soil gas surveys), and laboratory (XRD, SEM-EDS) based techniques to assess the spatial extent, physical structure, and mineralogy of surface hydrothermal alteration at Red Crater, Tongariro, Aotearoa/New Zealand. Surface weathering, and silicic and argillic alteration styles at Red Crater precipitate distinct assemblages including native sulphur, silica polymorphs, Fe- oxides (goethite, hematite), phyllosilicates (kaolinite, smectite), and sulphates (alunite). The active geothermal areas here are characterised by heated ground (~90°C), fumaroles (~100°C) and soil CO_2 fluxes of ~5.7 t/day. Our study aims to provide data to inform new models and forecasting methods for volcanoes with active hydrothermal systems.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Hydrothermal Weakening and Slope Instability at La Fossa Cone, Vulcano Island (Italy): A Combined Approach Using Drone Imaging and In-Situ Strength Testing

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Volcanic flank instability poses several significant risks, including caldera collapses, landslides, rock avalanches, and tsunamis, establishing volcanic edifice weakening as a multi-hazard threat. Among various triggering mechanisms, hydrothermal alteration is a well-established factor that degrades the physical and mechanical properties of volcanic rocks, facilitating destabilization processes. While previous studies have examined the physicochemical impacts of hydrothermal alteration, they were conducted in laboratory settings, leaving broader geophysical patterns and regional variability less explored. For this study, we chose La Fossa Cone (Vulcano Island, Italy), the southernmost part of the Aeolian volcanic archipelago, as our field site. With a history of hydrothermal alteration, episodic periods of unrest, and recent episodes of mass wasting, La Fossa Cone serves as an ideal natural laboratory. Here, we utilized a combined approach of high-resolution drone photogrammetry, image analysis and classification, and in-situ rock strength measurements to investigate the spatial distribution and intensity of hydrothermal alteration and its effects on rock strength. Our results revealed (1) a heterogeneous distribution of alteration intensities, (2) a strong correlation between increased alteration and decreased rock strength, (3) the identification of the weakest rocks on altered flanks, and (4) a spatial association between zones of hydrothermal alteration and areas of active erosion or landslides. This integrated approach enhances our understanding of the connections between hydrothermal alteration, rock strength, and volcanic flank instability, providing a novel framework for hazard assessment and mitigation strategies in volcanic environments.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Thermal Footprints of the Central Crater at Mt. Etna (Italy): Insights into Abrupt Changes in Surface Permeability, Hydrothermal Alteration, and Sporadic Thermal Anomalies

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Volcanic outgassing and hydrothermal alteration are well-known processes in volcanic edifices, typically controlled "bottom-up" by fluid overpressure, density contrasts, and fractures or faults that serve as pathways for volcanic outgassing at the surface. At the rim of the Central Crater of Mt. Etna (Italy), our studies have revealed a previously unrecognized mechanism driving these processes "top-down," creating distributed fumarole depressions up to 6 m wide and 1 m deep. These depressions, characterized by thermal exhalation and hydrothermal activity, were mapped using high-resolution geospatial data obtained with a drone equipped with an infrared sensor and an RGB camera, identifying over 100 anomalies. We find that many of them host basaltic bomb fragments, thus resembling bomb impact sites. Rock samples collected from selected locations were then analyzed using mercury intrusion porosimetry to gain further insights into the porosity and permeability characteristics of the material at depth. These findings offer a new perspective on how volcanic bomb impacts can influence abrupt shifts in surface permeability, thereby affecting outgassing pathways and associated alteration. Our interpretation of the results suggests that volcanic bombs from the May 21, 2023, South East Crater paroxysm impacted the surface, breaching an otherwise sealed surface and puncturing a hydrothermally altered cap. These impacts enabled localized pathways for outgassing, producing distinct thermal and alteration anomalies that control the locations of fumaroles along the crater rim. Furthermore, we discuss how this "top-down" fumarole formation may play an essential role in understanding volcanic outgassing efficiency, mineralization, and the structural stability of volcanic systems.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Quantifying hydrothermal system timescales at Tongariro volcano, Aotearoa New Zealand

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Hydrothermal alteration is known to enhance conduit sealing, modulate phreatic eruptions, and contribute to the weakening of slope stability. However, the timescales of alteration are poorly understood and difficult to constrain. Here we use new field- and laboratory-based observations and analyses of fresh and altered lavas from Tongariro, New Zealand, to reconstruct the timescales, fluid composition, and impacts of alteration at this volcano. We focus on Tongariro as it hosts a moderate-sized hydrothermal system across a distributed vent complex. Importantly, it is the site of recent phreatic eruptions in 2012. Fresh Tongariro lavas (~500 years old) contain variable plagioclase and pyroxene phenocrysts in an aphanitic groundmass with trace titanomagnetite. Respective altered equivalents are characterized by secondary phyllosilicate minerals, including kaolin-group minerals, and other phases such as pyrite and alunite, reflecting (advanced) argillic alteration caused by acidic fluid flow and/or acidic steam percolation at shallow depths at ~150-200°C. Notable, albeit rare, hydrothermal carbonates are present (e.g., dolomite). The rates of alteration of the primary lavas (e.g., using stratigraphy and/or radiometric dating) indicate that hydrothermal alteration can occur within years to thousands of years. Our detailed analysis of secondary mineral assemblages indicates complex and temporally evolving hydrothermal fluid chemistry (including pH) and temperature. The analyzed secondary minerals may represent alteration processes associated with the 2012 eruptions, involving deep magmatic fluid discharge followed by neutral meteoric water. Understanding these processes provides insights into hydrothermal fluid circulation, alteration history, and potential volcanic hazards including flank collapse and conduit timescales contributing to phreatic eruptions.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

3D micro-deformation in hydrothermally altered andesites - Alteration-induced rock fracturing or fracture-induced alteration?

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Volcanoes are inherently unstable, undergoing cycles of rapid construction and destruction due to eruptions and mass movements. Hydrothermal alteration weakens volcanic rocks, promoting phreatic eruptions via clogging outgassing pathways and volcanic landslide activity. This research quantifies the microscale effects of hydrothermal alteration on deformation. Micro-computed tomography (MCT) imaging at the Australian Synchrotron obtained high-resolution (6.5 μm voxel size) 3D maps of rock structures before and after deformation, complemented by scanning electron microscope (SEM) data from undeformed samples. Deformation experiments were conducted under 0, 5, or 10 MPa confining pressures, simulating conditions within a hydrothermal system. 35 samples from three New Zealand volcanoes—Ruapehu, Tongariro, and Whakaari—were analysed, representing a diverse range of alteration mineralogies (unaltered to phyllic), porosities (0.07–0.55), textures (e.g., flow banding, veining, brecciation, grain sizes), and lithologies (dense lava, scoria, breccia, other volcaniclastic). Digital image correlation of before-and-after MCT scans enable a detailed quantification of strain localisation and fracturing. Combined with textural and mineralogical analysis provided by 2D computed tomography images and SEM with energy-dispersive X-ray spectroscopy, the impact of hydrothermal alteration changes to rock properties is contextualised within the 3D deformation space. Our findings provide insight into how alteration influences strain localisation, fracture propagation, and deformation processes. These microscale observations can be upscaled to volcanic rock masses, shedding light on strain localisation in heterogeneous volcanic environments. Ultimately, this work advances understanding of hydrothermal alteration contributing to debris avalanche initiation and over pressurisation leading to phreatic eruptions, improving hazard assessment for volcanic systems.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Repeated drone aeromagnetic surveys to reveal shallow thermal activity at Tokachidake Volcano

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Magnetic surveys provide insights into subsurface temperature changes and rock alteration. Repeated aeromagnetic surveys are useful for detecting subsurface thermal activity in volcanoes (Koyama et al., 2022). Recently, drone-borne magnetic surveys have become practical, enabling researchers to collect aeromagnetic data independently and with flexibility. In this study, we conducted repeated drone aeromagnetic surveys at Tokachidake Volcano in Hokkaido, Japan, to identify ongoing thermal activity hidden in the shallow subsurface. Currently, geothermal anomalies are observed in regions slightly away from the crater of Tokachidake. We collected aeromagnetic data around the crater at a constant clearance above the ground using a drone in 2023 and 2024. From these datasets, we retrieved temporal changes in magnetic anomalies and investigated three-dimensional magnetization changes in the shallow subsurface. We modeled the distribution of magnetization changes with a 3D inversion code by Koyama et al. (2021). The model imaged a demagnetized region in the shallow part of the geothermal anomalies, likely caused by heating or alteration of subsurface rocks due to hydrothermal fluid intrusion. Conversely, a remagnetized area was imaged beneath the crater, possibly reflecting the cooling of subsurface rocks due to a decrease in the supply of hydrothermal fluids to the crater. These results suggest a shift in hydrothermal fluid flow, with a new supply route forming toward the geothermal anomalies. This shift may weaken subsurface structures through hydrothermal alteration, increasing the risk of sector collapse.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Mineralogical studies and sulfur isotopic characteristics of volcanic ash from phreatomagmatic eruptions -Case studies of Aso volcano, Japan-

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Sulfur-bearing minerals from volcanic eruptions are commonly found in volcanic ash. Analyzing these sulfur minerals provides valuable insights into the processes of eruptions. This study aims to determine the origin of sulfur-bearing minerals from volcanic ash and to understand the condition of the hydrothermal system during each activity. We examined the volcanic ash from Aso 2021 eruptions, Oct-14th-2021 and Oct-20th-2021. Ash samples collected on the day of the eruptions were analyzed. We prepared bulk samples for XRD analysis, chemical extraction, and sulfur isotope analysis, and untreated samples for polished sections for SEM-EDS analysis. For sulfur isotopic analysis, we performed sequential extraction to separate sulfur from different minerals: water-soluble sulfur, native sulfur, calcium sulfate (gypsum and anhydrite), alunite group minerals, and pyrite. Coarse ash grains in ash aggregates observed by microscope are primarily volcanic glass shards and hydrothermally altered rock fragments. The Oct-14th-2021 bulk sample contained natroalunite, alunite, pyrite, gypsum, anhydrite and plagioclase from XRD analysis. The Oct-20th-2021 bulk sample contained cristobalite, in addition to the minerals mentioned in the Oct-14th-2021 sample. The isotopically fractionated values indicate that sulfide minerals and sulfate minerals from the Oct-14th-2021 sample were in equilibrium in a hydrothermal system. The changing δ34S suggests that the ratio of minerals directly condensed from magmatic gas between the two eruptions increased and fluctuated.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Unravelling alteration processes at Adatara volcano in the laboratory

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Adatara volcano in Fukushima Prefecture (Japan) plays host to multiple complex hydrothermal processes, broadly divided across four alteration zones. Operative reactive processes include pyrite alteration, the formation of clays, silica redistribution, and precipitation of sulfates and other minerals. Intriguingly, evidence for low-temperature hydrothermal alteration is found in direct contact with zones of extreme high-temperature alteration, highlighting that the reaction conditions (pressure-temperature-composition: PTX) are highly spatially and temporally variable. Through a series of batch reaction experiments and hydrothermal flow-through experiments at elevated temperatures and pressures, we aim to "reverse engineer" some of the diverse alteration textures observed in the field. In turn, this will allow us to map out the PTX parameter space dominating the different alteration zones, and give insight into volcanic hazards at Adatara volcano – a volcano characterised by cycles of phreatic and magmatic explosive activity, but not by extensive collapse events akin to the neighbouring Bandai volcano. The novel flow-through apparatus comprises a pressure vessel encased in a custom-fabricated heating mantle. A combination of fluid pumps allows the delivery of hydrothermal fluids (e.g. sulfuric acid) through nominally pristine volcanic materials. Sensors allow us to track permeability changes over time, providing insight into pressure generation or dissipation mechanisms in the volcanic setting as a function of geochemical processes. In concert with extensive geochemical characterisation, field surveying, and reactive modelling, these experiments form part of a larger effort to understand the nature of the hydrothermal system at Adatara Volcano.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Silicification Processes of the Goderdzi Petrified Forest: Insights from Mineralogical Studies

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The Goderdzi Petrified Forest, of the Late Cenozoic Samtskhe-Javakheti volcanic highland, located near the Goderdzi Pass in southern Georgia. It is a remarkable site featuring petrified trees preserved within the tuffaceous sediments of the Upper Miocene–Lower Pliocene volcanogenic Goderdzi Formation. This fossil flora is distinguished by its exceptional preservation and diverse species composition. Goderdzi fossil trees first studied in the early 20th century and approximately 200 species have been identified.

Recent research has identified 11 new subtropical species, with no boreal representatives. The petrified wood exhibits diverse silica mineralization, including amorphous opal (opal-A), opal-CT, and quartz. Many samples display a mixture of opal-A and opal-CT, the latter being a weakly crystalline form of opal containing cristobalite and tridymite interlayers. The transformation of opal-A to opal-CT is thought to occur through silica dissolution and reprecipitation, though opal-CT may also form directly as a primary precipitate. The petrification process begins with the deposition of amorphous silica in cell walls, followed by the infilling of cell interiors (lumens) and large conductive vessels. The final silica forms—opal-A, opal-CT, chalcedony, or quartz—depend on factors such as silica concentration, temperature, wood permeability, and episodic silica-rich groundwater infiltration. The dominance of opal-A, a less stable silica form typically associated with young deposits, aligns with the Pliocene age of these fossils. XRD patterns analyses reveal a range of silicification histories, including specimens dominated by mixtures of opal-A and opal-CT, as well as quartz-rich samples. These findings suggest a multi-stage silicification process influenced by volcanogenic host rocks.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

The effects of hydrothermal alteration in the upper edifice of Copahue volcano (Argentina-Chile)

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Copahue volcano, located at the border between Chile and Argentina, has been among the most active volcanoes in Patagonia for the last 30 years. Due to its high activity and proximity to nearby villages and tourist areas, Copahue is considered the volcano to pose the highest risk in Argentina. Copahue hosts a hyperacidic lake in its active crater, and many surface manifestations of extensive hydrothermal activity. While the geochemical composition of the lake and sources are well studied, no work has been published on the effect of this active volcano hydrothermal system on the edifice rocks. Here we study the upper edifice of Copahue volcano with muon radiography, used to infer the density structure in the east flank, and laboratory analyses of 11 rock samples that were collected from the volcano. Using a Scanning Electronic Microscope (SEM) combined with Energy Dispersive X-ray analysis (EDX), we visualize the effects of alteration and identify the minerals present. The different minerals are also further characterized by X-ray Powder Diffraction (XRPD). Furthermore, we measured density, the dry uniaxial compressive strength, and static Young's modules for all 11 blocks. The muon image reveals strong density contrasts between an edifice made of fresh andesite and notably lower bulk densities beneath the crater lake. It also maps the presence of lava flows, ash and ice in the subsurface, which correlate with satellite imagery and on-site observations. The laboratory analyses reveal a large scope of degrees of alteration and physical properties that will be discussed.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

On the historical phreatic eruptions of Milos (Greece): an intertwined seismic/volcanic hazard?

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This work describes the Thiorichio phreatic crater field (Milos, Greece), located in a horst-type structural high (alt. ≃200 m) of a volcanic arc island. These craters, which cover an area of 1 to 2 km^2, are 15 to 20 m in diameter, 3 to 4 m deep and coalescing, suggesting successive local phreatic eruptions over a short period of time (Fontaine et al., 2003; Chiodini et al., 2023). The NW-SE strike of the field (*i.e.* sub-parallel to the Fyriplaka graben) ends south of Thiorichia (old sulphur mines) where the occurrence of these craters suggests genetic links with active tectonics, offshore hydrothermal seeps, and landslides. Using structural and sedimentary field observations, a regional topographic survey and drone photomosaics, we show that groups of 5 to 10 craters line up along several directions (NE-SW, N-S and NW-SE). The age of the eruptive craters is confirmed by pottery of probable Hellenistic age (≃2300 y B.P.) found into the phreatic cones. The potteries present in coarse volcaniclastics are draped under several centimetre-thick layers of volcanic ash. In terms of geological hazards, these observations lead us to (i) reconsider the source areas of the phreatic eruptions that probably led to the destruction of Aghia-Kyriaki (*e.g.* Traineau and Dalabakis, 1989; Photos-Jones et al., 1999) and (ii) support that the occurrence of a large earthquake (Mw > 5) on Milos could rupture the hydrothermally self-sealed cap system of fractures, depressurizes and chaotically drains the fluids (water, gases) probably trapped at the hypocenters of the underlying earthquakes.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Trace metals in hydrothermal systems: Northern Volcanic Zone, Iceland

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High-enthalpy hydrothermal fluids are an important source of clean energy for the green transition. Apart from heat, they also transport volatile elements from the deep Earth to the surface, contributing to element cycling between the lithosphere and the atmosphere. Hydrothermal fluid composition is the result of multiple processes and sources. In particular, the processes of magmatic degassing and fluid-rock interactions contribute to the trace-element load of these fluids, while meteoric water dilutes them. In previous work from our group, we combined trace metal signatures in down-well and surface geothermal fluids with fresh and altered reservoir host rock compositions to estimate the relative contributions of magmatic outgassing and fluid-rock interactions to the trace-metal budget of deep fluids in the Northern Volcanic Zone of Iceland. The surface fluids are depleted in base metals compared to deep-sampled fluids indicating a need to understand the sources and sinks of metals in hydrothermal fluids to interpret surface fluid compositions. Our data comprises stable water isotopes ($\delta^{18}O$, $\delta^{2}H$), Sr isotopes ($^{87}Sr/^{86}Sr$), noble gas isotopes (He, Ne, Ar, Kr, Xe) and trace metal analyses of wells in the Krafla, Bjarnarflag and Þeistareykir geothermal stations of the NVZ. Using correlations between isotopes and trace elements combined with geochemical modelling, we identify multiple sources of fluids, correcting for processes such as boiling and scale precipitation that alter the deep fluid composition, and providing insights on the sources of metals in these deep crustal fluids.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Reconstruction of the dynamics of hydrothermal explosions based on ballistic ejecta characterization - Insights from Pocket Basin, Yellowstone National Park

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Phreatic and hydrothermal explosions are sudden, violent events driven by the explosive vaporisation of near-boiling, pressurised water, which form characteristic craters, breccia deposits and ballistic strew-fields. Such explosions are controlled by the properties of the host rocks and any secondary alteration. Studying the lithologies in hydrothermal explosion breccias can allow to reconstruct the pre-explosive conditions in the subsurface reservoir and, combined with laboratory experiments, help decipher the explosion dynamics. Yellowstone National Park attracts more than 3 million visitors annually with its diverse geothermal manifestations. The Yellowstone Volcanic Field also hosts the largest number of hydrothermal explosions globally, ranging from small to the largest ever documented. However, much is still unknown about the triggers and reoccurrence intervals of these explosions. Pocket Basin is a large (400×800m) hydrothermal explosion crater that likely formed around 13–14ka. We mapped the distribution of ballistics and studied their variably hydrothermally altered lithologies applying a combined approach based on petrophysical, experimental, and analytical techniques to gain insights into the explosion dynamics and conditions that primed the explosion. Our results show that the prevailing silicic-argillic alteration of Pocket Basin rocks reduces porosity and permeability and increases the fragmentation threshold. Textural elements such as lithic clasts, crossbedding, and pre-explosion brecciation further influence petrophysical properties and fragmentation behaviour. The high pressure-temperature conditions required to induce fragmentation in saturated samples support the presence of a lake above the pre-explosive reservoir that would have increased confining pressure on the system. Rapid draining of the lake may have triggered the explosion.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Hydrothermal alteration and fluid circulation in a collapsing volcano (Askja caldera, central Iceland)

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Large caldera collapses are some of the most dramatic geological phenomena, often involving complex interactions between faults and hydrothermal fluid circulation. This study focuses on the Askja caldera (central Iceland) where a massive landslide occurred in 2014, exposing to surface a wide range of altered rocks, thus providing a unique opportunity to investigate the relationship between fluid circulations, alteration processes, and faulting. Characterization of the different alteration styles within the landslide area aims to characterize the involved fluids and their compositions. This study also explores the potential interaction between structural features, such as caldera ring faults, and specific fluid circulations, as triggers to the landslide process. We collected a series of samples during a field mission in August 2024, mostly within the products of the 2014 landslide, and identified their origin on the landslide wall. The main types of alteration were identified affecting basalts and rhyolites (calcite, zeolite, pyrite, hydrothermal quartz). Petrography, XRF, XRD, optical-CL, Raman spectroscopy, QEMSCAN, microprobe and LA-ICP-MS have revealed that the observed alterations resulted from two distinct fluid systems circulating through the landslide area. Additionally, hydrogen and oxygen stable isotope analyses could help inferring the origins of these fluids, further elucidating their role in the alteration processes. Our results shed light on the structural control of hydrothermal alteration in collapsed calderas, advancing our understanding of the mechanisms driving caldera instability and landslides.

Theme: 3. Volcanic processes

Session 3.8: Hydrothermal alteration in volcanic systems

Allocated presentation: Poster

Influence of subsurface soil and lithology alteration on degassing at Krafla Caldera, Iceland

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Rock-fluid interactions significantly alter rock and soil properties, influencing fluid flow within hydrothermal aquifers, shaping surface features and degassing over time in geothermal settings. Understanding the spatial distribution of thermal manifestations in relation to geological settings and alteration types is crucial for revealing the processes that control fluid transport from subsurface aquifers to the surface. While past studies have focused on alteration effects within hydrothermal aquifers on a scale of hundreds of meters, limited research has examined the influence of subsurface lithologies, including their permeability (both intrinsic and altered) and spatial distribution on degassing activity. The present study investigates the relationship between subsoil lithologies and degassing zones in the active geothermal fields of Krafla caldera, Iceland. Specifically, it explores how hydrothermal alteration affects the petrophysical properties of these lithologies, thereby influencing surface fluid circulation. In 2022 and 2023, we conducted two field campaigns, assessing the in situ petrophysical properties of over 200 samples from 22 sites in the Víti and Hveragil regions. We also measured subsoil diffuse CO_2 flux at specific profiles. Permeability values ranged from 10^{-11} to 10^{-16} m^2, with CO_2 fluxes varying from 1.25 to 2628.33 g m^{-2} d^{-1}. Grain size distribution and componentry analysis were performed on selected subsoils. Our findings reveal both active and inactive geothermal regions, illustrating the varying impacts of hydrothermal alteration. In active zones, mineral dissolution creates fluid flow pathways, while mineral cementation in inactive zones hinders fluid movement, providing key insights into the dynamics of fluid transport and degassing in geothermal settings.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Talk [Invited]

Precursory Pressure Signals of Pyroclastic Density Currents

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Pyroclastic Density Currents (PDCs) are complex gravity currents that are significant hazards during volcanic eruptions and are highly destructive to the natural and built environment, making them uniquely challenging for obtaining direct measurements. Thus, acoustics and seismo-acoustics have been investigated as a tool for interrogating PDCs in situ. We show through the use of large-scale analog experimental PDCs that these flows generate atmospheric pressure waves. We record and analyze two fundamentally different types of precursory pressure signals that precede the arrival of the flow. The first is an acoustic wave that is generated by the initiation of the PDC and the initial intrusion into the atmosphere like a dome collapse or column collapse. Additional pulses are generated by the underflow potentially leading to the ability to distinguish types of PDCs. This is consistent with early observation of pressure waves generated by dome collapse events at Unzen volcano in Japan. The second pressure signal is produced by drag by the front of the PDC in the ambient air. This significant increase of dynamic pressure immediately preceding the flow arrival is comparable with the dynamic pressure within the flow proper. Precursory pressure waves generated by PDCs should therefore be taken into account in hazard models for PDCs as we show that they have the potential to produce dynamic pressures on par with PDCs themselves. Identification and classification of precursory pressure signals from PDCs can lead to improved early warning systems and hazard mitigation.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Talk

Rheology of granular flows: implications for pyroclastic density currents

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Pyroclastic density currents (PDCs) are gravity-driven, hot, gas-particle mixtures that travel away from volcanic vents at speeds typically of the order of tens of metres per second. PDCs transport particles from micron-sized ash to clasts larger than a metre. High temperatures, large velocities and their ability to travel great distances on slopes of just a few degrees makes PDCs one of the most lethal geophysical flows. Such properties also make PDCs incredibly complex and, due to their destructive nature which limits direct observations, one of the least understood volcanic phenomena. Yet, understanding of the internal structure and the rheology of PDCs is crucial to accurately forecast the flow path and the run-out distance of these hazardous flows. This research investigates the rheology of fluidised granular columns through novel experiments where a granular mixture is simultaneously sheared and fluidised whilst the pressure, stress and apparent viscosity are measured. Firstly, we study the effects of the applied shear on the fluidisation behaviour of monodisperse granular mixtures comprising spherical glass beads. Secondly, we explore the rheological regimes of monodisperse and bimodal granular columns with variable particle volume fraction. Finally, to quantify the effects of the particle shape on the fluidisation and rheological behaviour of the granular mixtures, we perform the experiments using real pyroclastic material and compare the results with the glass beads data. The findings from this work can be used to inform large-scale simulations of fluidised granular flows comprising particles of various sizes and shapes, propagating over non-uniform topographies.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Talk

The interaction between Pyroclastic Density Currents and waterbodies, first results from PELE large-scale experiment

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Pyroclastic Density Currents (PDCs) can generate tsunamis and cross significant waterbodies posing high risk to populations living in near-shore volcanic areas. Global hazard assessments urgently require models for mitigating this risk, but the hostility of flows persistently defies any internal observation of this enigmatic hazard process. By synthesizing PDC-water interactions in large-scale experiments, we demonstrate that three fundamentally different types of water wave occur, depending on the vertical density stratification of the parental density current. Through direct measurements of the sub-aerial and sub-aqueous flow regions, we show that the wavelength, wave celerity, the ratio of wavelength and water depth, and the wave energy, increase by orders of magnitude with increasing concentration of the basal PDC flow region. Dilute turbulent surge-like PDCs generate low-energy shear-induced wind-waves. For more concentrated PDCs, a higher energy, soliton-type wave occurs through the instantaneous transfer of momentum from the dense underflow of PDCs to the near-shore waterbody. Importantly, for sustained eruption conditions, the prolonged momentum transfer from the underflow onto the water generates an extremely high-energy, long wavelength wave. This high-celerity wave can overtake earlier generated soliton-like waves and has never been reported in experimental and numerical simulations. The types and characteristics of real-world waves can be predicted by considering the momentum fluxes and duration of natural PDC events. This discovery suggests that tsunami hazard models should consider generation of multiple waves by a single PDC and must account for the vertical density stratification and for temporally variable momentum of PDCs to accurately predict hazard impacts.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Talk

Emplacement mechanisms of pyroclastic density currents: insights from numerical simulation of dense granular flow with pore gas pressure

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^The dense basal part of pyroclastic density currents (PDCs) is made up of rock fragments, ash and hot gas. These granular flows behave like fluids and can travel distances of several tens of kilometres on almost horizontal slopes. A better understanding of the physics and mechanisms controlling PDCs emplacement is a major challenge in volcanology. We propose a dense fluidized granular flow model that takes into account the pressure of the interstitial gas. A key point is that the model is two-dimensional, which permits us to investigate the internal dynamics of the flow and in particular the spatio-temporal variation of the interface separating the deposit and the overlying moving layer. This two-dimensional model is based on the equations of conservation of mass and momentum with the μ(I) rheology. We consider the configuration of the sudden release of a dense fluidized granular column and compare our results with those of laboratory experiments. The numerical simulations recover the main characteristics of these flows, namely the shape of the granular mass during collapse, the temporal evolution and speed of the front, and the internal dynamics. In particular, the position of the interface betweenthe basal deposit and the overlying moving layer is captured with accuracy. The interface migrates towards the surface as the granular material spreads and until the mobile granular layer is consumed. The use of a non-averaged model is essential to recover this particular behaviour. ^

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Talk

Multiphase Modeling of Density Current Interactions with Topography: Insights into Depositional Processes

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Understanding pyroclastic density currents (PDCs) requires addressing their complex interactions with topography, where flow dynamics, turbulence, and sedimentation processes vary significantly. *We employ a novel multiphase OpenFOAM solver to simulate flume experiments replicating dilute PDC behavior and interactions with topography.* The high-resolution, parallel simulations inject a water-alcohol mixture, along with multiple particle classes, into domains featuring simple topographies such as flatbeds, hills, and valleys. Buoyancy reversal, induced by particle sedimentation and the alcohol-water mixture's lower than ambient density, effectively mimics key dynamics of natural PDCs, including their transport and deposition. We compare our simulation results to notable features, such as climbing dunes and variations in deposit thickness on stoss and lee slopes from experimental flume runs. Our simulations also incorporate multiple particle size classes and time-varying inlet conditions, which better replicate natural geological scenarios. By integrating experimental and numerical approaches, this work provides critical insights into how PDCs interact with and are influenced by complex topography. While the current focus is on water-based flows, the methodology is adaptable to dilute PDCs, as well as turbidity currents, since the main non-dimensional numbers characterizing these experimental and simulated flows are in the range of real PDCs. These results advance our ability to interpret flow dynamics from deposits, contributing to the broader understanding of pyroclastic surge behavior, sedimentation processes, and flow interactions with topographic obstacles. Ultimately, this work aids in refining volcanic hazard assessments and reconstructing PDC dynamics in diverse geological settings.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Talk

Fountain-like collapse of an eruption column during a large explosive eruption

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Fountain-like collapse of eruption columns has been observed in numerical simulations of explosive eruptions, but such a style of collapse is rarely documented by field observations. The contrasting characteristics of the proximal and distal tuffs (~6.5 km^3 in volume) from the 34-ka Sounkyo eruption at the Ohachidaira caldera, Japan, may reflect complex processes of column collapse. The features of the distal welded tuff are most consistent with emplacement by pyroclastic currents from a fountain of the jet core, in which air entrainment was negligible so that the collapsing mixture remained sufficiently hot and dense to allow welding and retention of fines. In contrast, the fines-depleted, nonwelded, and stratified nature of the volumetrically minor proximal tuffs may require substantial entrainment and expansion of cool air into the mixture. Such enhanced entrainment of air might have been related to the margins of the jet, while its core formed a fountain and the distal tuff. The distal tuff contains more abundant pumice (relative to scoria) clasts than the scoria-richer proximal tuffs, and this might reflect heterogeneous distribution of the two components in the columns. Before fragmentation, a silicic magma-rich core was likely surrounded by the mafic magma-rich margins due to viscosity segregation. Such a process is consistent with the fact that some wall-rock lithic clasts are thinly coated by scoria or incorporated within scoria clasts but never associated with pumice. The distribution of the deposits and their relations to the substrate topography imply a fountain height and an impact distance of >3 km.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Talk

Dynamics of granular flows in volcanic environments: insights from analogue experiments

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Volcanic dense granular flows, such as pyroclastic density currents and debris avalanches, pose major hazards around volcanoes. Field-based, experimental, and numerical studies commonly deal with the dynamics of these flows but few of them address the physical processes of granular fingering that cause remarkable surface structures. Here, we investigate granular fingering using laboratory experiments with polydisperse materials released on an inclined rough substrate. A statistical analysis of the results reveals how the initial parameters (particle size range, volume of material, and slope angle) and the flow parameters (volume flux) control the geometry of the granular fingers that form ridged deposits. The flows require a critical slope angle (24° - 30° for glass beads) and a critical volume to travel down and form deposits with finger patterns. The slope angle, the material volume as well as the particle size distribution control the onset of granular fingering but these parameters have little effect on deposit morphology. However, the width of the fingers is controlled by the volume flux of the flows. We find a well-defined power law relationship between the finger width and the volume flux. Considering finger widths observed in nature, we use this power law relationship to infer the volume flux and hence the velocity of some volcanic granular flows. Application to pyroclastic ridged deposits of the last eruption at Tutupaca volcano, Peru, gives parent flow velocities of 8-30 m/s.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Can you stop a PDC? Assessing the impact of vertical topographic barriers on channelised, aerated, dense granular currents

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Pyroclastic density currents (PDCs) are hazardous volcanic flows that have the potential to surmount topographic highs. Topography can deflect or reflect PDCs and topographic barriers are sometimes used to delineate inundation areas in hazard assessment. However, how PDCs interact with topography is not well understood. Past experimental studies have found that all (or part) of a dilute current can overtop topography, depending on the height of the barrier with respect to current thickness and the momentum of the flow. The effect of topography on the basal granular layer of a PDC has not previously been investigated. Here, we quantify the effects of different vertical topographic barriers (varying in height and barrier position relative to the current source) on flow velocity, runout length and the behaviour of aerated dense-granular currents (analogous to dense granular PDCs) in an experimental flume. Short lived (<3 s) currents are allowed to propagate downstream from source and impact the barriers. Our results show that the nature of current interaction with a barrier is dependent upon the ratio of barrier height to current thickness ($h_{barrier}/h_{current}$). For instance, values of $h_{barrier}/h_{current}$ of <~2.7 result in the arriving current lifting off and following a ballistic trajectory as it overtops the barrier. Our results indicate a linear trend between normalised runout length and $h_{barrier}/h_{current}$, and suggest that a vertical barrier needs to be ~4.8 times higher than current thickness to block a channelised dense, granular current. Future analysis will focus on depositional processes and resultant analogue deposits.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Revealing the key role of the substrate in pyroclastic flows using small-to-large scale experiments

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During explosive volcanic eruptions, the collapse of lava domes or eruptive columns can generate pyroclastic density currents, which then propagate at high velocity over considerable distances, destroying everything in their path. While the upper dilute cloud, often referred to as *pyroclastic surge*, can be satisfactorily described as a turbulent gravity current, the basal concentrated granular avalanche, known as *pyroclastic flow*, is more difficult to model, suggesting that physical processes are still missing. The interaction between the pyroclastic flow and the substrate, which can vary considerably due to the nature of the deposits in past events, is one of the mechanisms that may explain their high mobility compared with experimental flows. To better understand and model the flow-substrate interaction, we investigate the role of the substrate roughness on the dynamics of concentrated granular flows using small-to-large scale experiments. We reveal that the nature of the substrate can significantly affect the stability, dynamics and deposition of granular flows. More specifically, we identify three types of substrate - smooth, rough and macro-rough - based on the size ratio between the flowing material and the substrate roughness, for each of which we characterize the macroscopic flow properties. This study offers guidelines for improving the modelling of pyroclastic flows and, more generally, of geophysical granular flows.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Experimental study of the formation of dilute or concentrated pyroclastic currents in the impact zone of eruptive fountains

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The conditions that control the nature of pyroclastic density currents (i.e., fully dilute and turbulent or with a concentrated base) that form in the impact zone of a collapsing fountain remain poorly understood. We address this question through laboratory experiments to better understand the degree of air-particle coupling during the impact of a dilute mixture on a solid surface. We released quasi monodisperse glass beads (mean sizes: 29 - 269 μm) from a hopper placed at a height of 1.63 or 3.27 m above a 5 m-long horizontal channel. Grids were installed in the hopper to create highly dilute air-particle mixtures. The granular mixtures accelerated and diluted further as they dropped from the hopper. We made precise measurements of the particle concentrations and fall velocities of the mixtures by acoustic measurements and high-speed imaging, respectively. We found that the particle concentration in the impact zone of the channel varied from 15 to 0.3 vol.%, depending on the particle size, the grid, and the fall height. We show that, depending on the particle size, concentration, and fall velocity, the mixtures either remained dilute, with particles coupled to the air, or transformed into concentrated flows. The Stokes number (St) is a key parameter in characterizing air-particle coupling in the impact zone. We determine a scaling law between St and the particle concentration of the mixtures that characterizes the transition between dilute or concentrated regimes. Finally, we discuss our results in the framework of recent numerical simulations and their applicability to natural systems.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Analysing the rheology of diverse volcanic granular flows with a new open-source coarse-graining tool.

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Granular flow processes with varying types of interstitial fluid and coupling regimes are ubiquitous in volcanology: from concentrated underflows in pyroclastic density currents, to debris flows, and crystal mushes in magma. However, the behaviour of these highly complex granular flows remains poorly understood. Modelling of granular flows through software packages that couple the Discrete Element Method (DEM) with Computational Fluid Dynamics (CFD) can provide detailed information at high temporal and spatial resolution of particle-particle and particle-fluid interactions. As such DEM-CFD approaches provide an invaluable tool to study the small-scale behaviour of granular flows, and are instrumental in the development of constitutive models used to understand rheology of granular materials. DEM-CFD models yield fundamental physical properties, for instance: particle force and velocity, (for solid phase) and fluid pressure (for fluid phase). To obtain continuum fields of relevant variables from discrete data (e.g., stress and strain tensors, pressure etc.), DEM-CFD outputs must be processed through a method called Coarse-Graining (CG). In this work we present a new python-based CG package designed to: maximise computational efficiency through -amongst other strategies- parallel computing; be user-friendly; and open source. Our tool postprocesses output files of DEM-CFD software packages, such as MFiX and LAMMPS, and yields outputs ready to render on the ParaView visualisation software. We present exemplar applications for a fluidised bed and a granular flow impacting a bend and make the case that our tool could be usefully applied to other areas such as crystals and magma in a conduit, or impact cratering.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Shape evolution of pumice during granular flow

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Explosive volcanic eruptions are a major geo-hazard. Direct observation of key phenomena is essential for improving hazard assessment. However, this is often unfeasible and information is generally inferred from volcanic deposits. During explosive eruptions, felsic magma fragments into angular, porous pyroclasts, transported into a buoyant eruption plume or into ground-hugging currents of variable particle concentration and flow turbulence. Depending on granular temperature, clasts change size and shape. The in-situ production of ash contributes to flow's mobility, enlarging areas at threat. To understand their transport and modification during granular flow, we performed three types of tumbling experiments using 2 kg lapilli from the 13 ka Laacher See eruption. At 5 experimental increments, the starting material was sieved at 2 mm. Ash generation was as high as 48 wt.% after 120 minutes. Shape evolution was investigated for 100 painted clasts with known petrophysical properties (volume, porosity) via four morphological (*Axial Ratio*, *Convexity*, *Form Factor*, and *Solidity*) parameters. Size and roughness evolved and allowed for quantifying volcanic ash generation and shape changes framing them in a specific relaxation theory. We have framed the analysis of the experimental findings in terms of effective relaxation times, whereby pyroclasts display a decelerating rate of change, on their approach to a time-invariant state of shape and roughness. This quantification of the susceptibility of porous pyroclasts to shape and size changes enhances our understanding of transport processes. Thorough field characterization of volcanic deposits will aid upscaling the experiments to natural processes, serving thereby to help mitigate volcanic hazards.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Collapse and entrainment of perched, metastable, volcaniclastic sequences as a key PDC generation mechanism: Volcán de Fuego June 2018 PDCs and analogue experiments

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During the June 3rd, 2018, eruption of Volcán de Fuego (Guatemala), incremental collapse of perched volcaniclastic sequences generated PDCs which travelled ~12 km with total volume of ~50 Mm^3. PDCs originating from collapse of metastable deposits which accumulate near the summit on slopes of 25°–40° over months to years, have occurred at Fuego again since, and are also known elsewhere. The specific triggering mechanism and dynamics by which material mobilises and is entrained remains poorly understood. The process is potentially common at persistently active explosive volcanoes, and is important due to the potential to form significantly larger flows than might otherwise be generated. Limited availability of observational and geophysical data means analogue experiments are vital for exploring these processes. Here, we use experiments of sand avalanches to investigate entrainment of erodible beds, employing high-speed imaging and Particle Image Velocimetry (PIV) to measure granular temperature—a key factor in rheology and flow-substrate interactions. We investigate how granular temperature transfer destabilises erodible substrates, weakened through granular heating. When shear stresses in flowing material reach sufficient levels, flows initiate collapse of underlying deposit, which trigger retrogressive dilation waves inducing wholescale pile failure. This represents a PDC generation mechanism which previously has not been recognised. We have also examined material accumulation in the ravine Las Lajas over time to understand the dynamics of metastable piles. An improved understanding of this generation mechanism highlights the importance of monitoring the accumulation of such 'piles' in order to understand how PDC hazard levels vary over time.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Dynamics and deposits of a two-layer model for pyroclastic density currents in magmatic and phreatomagmatic eruptions

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One of the most important challenges in volcanology is a unified understanding of the dynamical features of pyroclastic density currents (PDCs) and the characteristics of PDC deposits for various eruption styles such as magmatic and phreatomagmatic eruptions. We have developed a dynamical model for large-scale PDCs in magmatic and phreatomagmatic eruptions to explain both the dynamics and deposits of strongly stratified PDCs. In the model, the two-layer depth-averaged model consisting of upper dilute and lower dense currents (Shimizu et al. 2019) is combined with a thermodynamical model for magmatic and phreatomagmatic eruptions where the heat balance and phase changes associated with mixing of magma (pyroclasts and volcanic gas), external water, and air are considered (Koyaguchi and Woods 1996). The numerical results show that the run-out distance of upper dilute currents significantly increases with the increasing amount of external water due to the delay of lift-off. For a relatively small proportion of external water, the lower dense current tends to be absent due to the dilution of particle concentrations in the dilute current, resulting in the direct formation of the deposits from the dilute current in the entire area. These results capture the diverse features of natural PDC deposits of phreatomagmatic eruptions. In the presentation, we also discuss the topographic effects on the dynamics and deposits of large-scale PDCs by applying a two-dimensional (2D) depth-averaged model to the lower dense current. The semi-2D two-layer model successfully reproduces the valley-fill distribution of distal deposits.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Investigating the evolution of grain shape during transport inside various small-volume pyroclastic density currents over complex topographies

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Small-volume (< 0.5 km^3) pyroclastic density currents (PDCs) occur frequently and pose severe threats to populations and infrastructures surrounding active volcanoes. They are responsible for the two deadliest eruptions of the 21st century (Merapi 2010, Fuego 2018). Regardless of the generation mechanism, the complex topography of active volcanoes largely controls the dynamics, mobility and impacts of small-volume PDCs. A first compilation of grain shape parameters obtained from three well-constrained major PDC events (Merapi 2010, Calbuco 2015, Colima 2015) combined with detailed pre-, syn- and post-eruption data allows us to better understand the influence of varying topographic parameters on internal flow dynamics. Using image analysis with a Keyence VHX-7000 digital microscope, we observed ~5000 grains (of 250-300 microns size) per sample to measure circularity, roundness, solidity, convexity, and aspect ratio. Combining the data sets from the three targeted eruptions led to the identification of quantifiable relationships between grain shapes, deposit footprint and surficial/sedimentological features, retaining capacity of the receiving landscape, and scale-dependent tendencies for PDCs to overspill confined channels. For example, grains from valley-confined deposits are less circular and less convex than grains from overbank deposits of the same PDC unit, the latter also showing increases in all parameters with distance. Moreover, each type of PDC deposit yields grain shape parameters that plot within specific ranges of values, which are narrower for unconfined PDC units. These findings aim to expand on previous classifications of volcanic ash morphology to include data from small-volume PDCs to broaden the spectrum of explosive processes considered.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Field Investigation and Numerical Modeling of Deposit-derived Pyroclastic Density Currents in Punta Labronzo Area (Stromboli, Italy), from the Paroxysmal Activity of 1930

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Stromboli volcano (Italy) typically exhibits a persistent, low-intensity, explosive activity originating from its craters, located at about 750 m elevation over Sciara del Fuoco, a horseshoe-shaped depression on the NW flank, ≈2 km from villages. A few times per decade, the volcano can produce more powerful explosions, called paroxysms, possibly accompanied by Pyroclastic Density Currents (PDCs) from deposit instability. Outside Sciara del Fuoco, deposit-derived PDCs during the paroxysms in 1930 affected the NE basins that open towards inhabited areas, and in 1944 invaded the unpopulated basins to the SE of the craters. This study focuses on a small drainage basin on the North flank, tens of meters from the side of Sciara del Fuoco and ≈1 km from Stromboli village. There, at less than 200 m elevation, recent floods unveiled a previously unknown ≈1 m thick mass flow deposit intercalated between two spatter layers of the 1930 eruption and containing charred vegetation. Although componentry and grain size analysis present similarities with the larger flows in San Bartolo, the field samples at Labronzo show remarkably preserved older ash pellets engulfed by the flow, some of which with an accretionary hull. By performing depth-averaged flow modelling, we tested different assumptions on the source area, initial thickness, and dissipation parameters, indicating a volume $<10^4$ m^3 and independent dynamics from the other 1930 PDCs. A relatively low energy PDC synchronous to the fallout, would be consistent with historical observations of gravity flows of the hot deposits in the area.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Triggering and propagation of the 10 February 2022 pyroclastic avalanches at Mt. Etna (Italy): a multidisciplinary perspective

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Pyroclastic avalanches generated at basaltic volcanoes have drawn increasing attention in recent years due to their potential high mobility and associated hazards. These dense granular flows are mainly triggered by the collapse of pyroclastic fall deposits on steep slopes and can exhibit unexpected runout distances, even in low-slope terrains. In the period 2020–2022, volcanic activity at Mt. Etna (Italy) was characterized by intense paroxysmal eruptions at the Southeast Crater (SEC). In particular, on the evening of 10 February 2022, some pyroclastic avalanches were emplaced during an energetic lava fountaining episode. The largest one occurred at 21:26 UTC, following the gravitational collapse of a portion of the SEC's south flank. The resulting reddish-brown deposits extended up to ~1.4 km southward, partially covering the upper scoria cone of the 2002–2003 eruption, and have been stratigraphically subdivided into four units, ranging from fine ash to blocks. Here we present a multidisciplinary study combining field surveys, textural and granulometric analyses of selected samples, and remote sensing data to unravel the triggering mechanisms and flow dynamics of this event. Numerical modeling of the avalanche propagation further supports our findings, highlighting the influence of the morpho-structural and thermal conditions of the ultra-proximal deposits in the generation of the flow and its behavior. Our approach provides new insights into the dynamics of pyroclastic avalanches in basaltic volcanic settings, contributing to a better understanding of their hazards and risk assessment strategies at volcanoes like Etna, highly frequented by both researchers and tourists.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Co-ignimbrite plumes: insights from the deposits of the VEI 6 Pozzolane Rosse co-ignimbrite deposits (Colli Albani, Italy)

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Co-ignimbrites ash plumes commonly form as trailing ash clouds detached from ground hugging high concentration pyroclastic flows. The associated deposits are usually made of fine ash and may be dispersed over very vast areas. The co-ignimbrite deposits of the 460 ka, VEI6-7 Pozzolane Rosse ignimbrite from Colli Albani (Central Italy) are dispersed towards the east as far as Albania, covering more than 200,000 km^2. Unexpectedly, the co-ignimbrite fall deposits at 80-100 km distance from vent are lapilli-sized, made of scoria, accessory lithics and crystals as the parent ignimbrite. Reconstruction of the isopachs and isopleths of the co-ignimbrite suggests a minimum deposit volume of 16.5 km^3 and a column height >30 km. Based on previous numerical modeling of the pyroclastic flows generating the Pozzolane Rosse ignimbrite (Calabrò et al. 2022, JGR), we suggest that the associated co-ignimbrite plume formed largely at maximum runout, where buoyancy becomes positive and the pyroclastic flow lifts off, turning from horizontal to vertical at absolute velocities values up to >100 m s^{-1}, hence able to easily entrain dense lapilli-sized clasts, at mass fluxes of the same order of magnitude than those that fed the deposition of the ignimbrites. Such conditions are conducive to the generation of “rootless” buoyant columns at the front of the pyroclastic flow, comparable to Plinian in size and dynamics. The suggested mechanism is distinctly different from trailing co-ignimbrite ash clouds and may be modeled to infer source parameters of the parent pyroclastic flow based on co-ignimbrite deposits dispersal and grain size.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Size limits on particle rounding and their use in comparison between pyroclastic flow and fallout units

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Pyroclastic deposits provide a crucial record of explosive eruptive processes, which contribute to the construction of a volcanic record for a particular volcano or region. Common classification of pyroclastic deposits include the fundamental distinction between fallout units deposited as an air fall from an eruption column or plume and flow unit deposits from density currents and granular flows, the most common of which being pyroclastic density currents (PDCs). Rounded pyroclast shapes are commonly used as a primary feature to distinguish flow from fallout units. Furthermore, specific properties (e.g., the size and shape) of pyroclasts within fallout and flow units and details about the transition between units are useful for both modelling tephra dispersion and modelling PDC run out, and thus are important for hazard management. Here, we investigate pyroclastic deposits from Oregon, USA - the Bend Pumice and the Tumalo Tuff, a pumice-fallout and a pyroclastic flow unit, respectively. We analyse the deposits in terms of the particle size distribution and the shape of particles within each size fraction. These data are used to determine the shape parameters and grain sizes, that can be used to differentiate between the fallout and flow units. In doing this, we investigate several shape parameters to analyse the lower size limits on particle rounding and discuss the responsible energetics. Together these data inform on both deposit classification and secondary fragmentation processes within granular flows.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

High-Temperature Deformation and Failure of Welded Volcaniclastic Deposits: Implications for Deposit-Derived Pyroclastic Density Currents

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Failure of glowing volcaniclastic rocks can trigger hot rock avalanches, also known as deposit-derived pyroclastic density currents (PDCs). These phenomena are common in volcanoes with low to moderate eruptive activity, where steep slopes and proximal material accumulation near vents predispose volcanic flanks to instability. To investigate this process, we studied the welded deposits from the fire-fountaining activity of the1944 eruption of Mt. Vesuvius, which produced deposit-derived PDCs along the volcano's slopes. We combined field and laboratory analyses, as physico-mechanical analysis (porosity and sclerometer measurements, point load tests, uniaxial compression tests), and petrographic studies to examine the predisposing factors like welding degree, porosity, and crystallinity. In particular, high-temperature rheological experiments were conducted using the Volcanological In-situ Deformation Instrument (VIDI), capable of uniaxial deformation of volcanic material up to 1100°C. Tests were performed on partially remelted samples with varying welding degrees, including coherent lava blocks and partially welded pyroclasts. The experiments revealed the rheological response of multiphase materials (melt, crystals, and pores) The experiments explored the rheological response of multiphase materials (melt, crystals and pores) in regimes ranging from homogeneous to inhomogeneous deformation (viscous and brittle shear localisation). Flow curves defined material strength at elevated temperatures, while weakening due to shear band formation and ductile deformation was quantified. X-ray microtomography imaging before and after deformation provided insights into textural and porosity changes, revealing microstructural evolution during failure. These findings clarify the mechanical processes behind incandescent volcaniclastic rock failure and deposit-derived PDC generation, enhancing our understanding of volcanic instability dynamics and associated hazards.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Know your clusters to predict disasters – how hazard exacerbating particle-gas feedback evolves inside pyroclastic density currents

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Accurate predictions of the hazard intensity of PDCs necessitate models for the spatiotemporally evolving abundance of particles inside flows. The development of such models is challenging because the motion of particles inside PDCs is modified through long hypothesized but poorly understood feedback mechanisms between particles and gas. Particle-gas feedback occurs in PDCs because even the finest ash particles suspended in turbulence have significant inertia relative to the gas and cannot follow the rapid velocity fluctuations of the fluid. This condition leads to particle clustering, a reduction in particle-gas drag, and strongly enhanced sedimentation. The increased sedimentation should reduce flow-driving particle concentration, speed, and damage-causing dynamic pressure. Instead, recent measurements inside experimental PDCs demonstrated that the preferential clustering of particles at eddy margins causes one order of magnitude larger destructive power than predicted by conventional hazard models. Here we report measurements of the abundance and geometrical characteristics of particle clusters inside large-scale analogue PDCs of hot, polydisperse pyroclastic material and gas. The number density of clusters correlates non-linearly with the concentration of particles whose characteristic response time to fluid motion is similar to the characteristic fluid timescale. The characteristic length scales of clusters are characterized by turbulent spectra. Downstream, the mean length of clusters systematically decreases, while their thicknesses increase. Using energy spectra of flow-internal measurements of flow density, velocity and temperature, and tracking the particle-size distribution inside the evolving flows, we derive a model linking the geometric characteristics inside PDCs to the characteristic length- and timescales of coherent turbulence structures.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

A multi-faceted approach to estimate total grain size distribution of pyroclastic density current deposits using unoccupied aircraft systems, wet sieving, and high-resolution digital microscopy

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The study of pyroclastic density currents (PDC) dynamics, as well as related erosional and depositional processes still primarily rely on depositional evidence. Capturing data during an active PDC event is limited by hazardous conditions, as well as difficult logistical and technological challenges. Hence, acquiring geological samples that are analogous to individual PDC deposits is of the utmost importance, particularly for the quantification of the total grain size distribution (TGSD). Justifiably, volcanologists struggle to do so, as the grain sizes can range from a few microns to several meters, resulting in the commonality of truncated GSD data. Although different approaches have been proposed and used to estimate TGSD, improvements can be made to address the approximation of the buried portions of coarse clasts as well as enhancing the fidelity of the fine range partitioning. Thus, we developed a dependable and standardizable method aimed towards capturing the full range of grain sizes and reducing associated analytical uncertainties by melding different technologies. Complementarily, we used i) unoccupied aircraft systems (UAS) to capture imagery *in-situ* and then processed it to produce millimeter-scale Digital Outcrop Models (DOMs) for coarse-to-intermediate clasts (meter-to-centimeter scale), ii) traditional wet-sieving techniques for intermediate-to-fine clasts (centimeter-to-micrometer scale), and iii) a high-resolution digital microscope for the finest clasts (millimeter-to-micrometer scale). This approach aims to standardize the collection of PDC field data, contributes towards the adoption of discrete element methods to advance our understanding of PDC dynamics, and could even potentially improve volcanic hazard assessment efforts.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

The Kencherra Ignimbrite (Central Main Ethiopian Rift): a case study for assessing emplacement mechanisms of high-grade, welded ignimbrites

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Having been never directly observed, processes controlling eruption and emplacement of high-grade, densely welded ignimbrites still present many open questions. We focus here on the Lower Pleistocene rhyolitic "Kencherra Ignimbrite", an important marker bed within the volcanic stratigraphy of the Central Main Ethiopian Rift. The ignimbrite crops out along the eastern margin faults of the rift, covering a minimum area of 1000 km2 with a nearly constant thickness of 10-20 m. Internal stratigraphy is defined by a characteristic sequence of facies, with basal and top vitrophyres enclosing the main body of the ignimbrite. This presents a pervasive, sub-horizontal foliation defined by laterally discontinuous parting planes never showing clear rheomorphic deformation, and possibly results from progressive aggradation and strain from a sustained current. Microstructural data, microscopic observations, density measurements, rheological experimental data, geochemical and geochronological analyses were collected to shed new light on its peculiar emplacement processes. The analysis of strain indicators and the collected rheological data are used to discuss in detail the main mechanisms controlling the emplacement of the current and the shearing imparted by the overriding particulate flow. This ignimbrite represents an interesting and peculiar case to study the syn-eruptive sequence of agglutination, deposition and deformation which characterizes the emplacement of high-grade ignimbrite deposits.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

A global database of pyroclastic density current deposit field data: potential use for PDC modelling and hazard assessments

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The internal dynamics of pyroclastic density currents (PDCs) cannot be directly observed and much of our understanding of their complex physics is inferred from analysis of the deposits they leave behind. Data obtained directly from PDC deposits, such as grain size distributions and particle density, are key input parameters for numerical simulations of PDCs, and estimates of hazard impact metrics, used for hazard assessments. Comparison of numerical and analogue model outputs with field observations from natural PDC deposits can be used to validate the extent to which these models realistically simulate natural PDCs. However, our ability to compare and collate field datasets for integration with numerical and analogue models is limited by a lack of a publicly available database of PDC deposit characteristics. We present a global database of PDC deposit characteristics incorporating quantitative data (e.g., grain size, particle density, bedform dimensions) and qualitative descriptions of deposit appearance (e.g., sedimentary structures, lithofacies). The database includes data from 78 source publications, covering 97 eruptions, and 214 depositional units, from 55 volcanoes across 6 continents. Eruptions recorded in the database vary from VEI 1-8 and have magma bulk compositions ranging from trachybasalt to rhyolite. The database can be used for a variety of applications, including i) comparison of single deposit case studies to global datasets, ii) informing numerical and analogue model input parameters, iii) validation of numerical and analogue models against a wide

variety of natural deposits, iv) calculating hazard impact metrics of PDCs from past eruptions to inform hazard assessments.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Quantifying "boiling-over" versus discrete eruption column collapse to predict the timing and intensity of pyroclastic density currents

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Field and eruption modelling studies show that explosive eruptions in collapsing fountain regimes produce deadly pyroclastic density currents (PDCs) that can originate from relatively high column collapses and are linked to discrete, dilute and relatively thin PDC flow deposit layers, sometimes interbedded with fallout layers. Collapsing eruption columns can also emerge in or evolve to a continuously collapsing "boiling-over" regime linked to massive and relatively thick ignimbrite layers. We use scaled analog experiments on multiphase fountains to show that the period between fountain collapses compared to the time for ground-hugging gravity currents (GCs) to flow out of the impact zone forms a Collapse Frequency number (C_f) that predicts the timing and intensity of PDCs. For relatively strong fountains with $C_f < 1$, collapse occurs less frequently via periodic sedimentation waves to produce discrete GCs. As fountains become weaker with $C_f \geq 1$, collapses occur more frequently such that collapsing sedimentation waves merge in the impact zone and provide a continuous mass flux to GCs. We suggest that C_f quantitatively defines a continuous eruption source parameter space between discrete and continuous eruption column collapse regimes, can be used to predict PDC timing and intensity during eruptions, or be inferred from deposits to constrain eruption source parameters post-eruption. Future work should investigate how column collapse processes, distinct from sedimentation waves, influence the effective value of C_f.

Theme: 3. Volcanic processes

Session 3.9: Multidisciplinary Advances in Understanding Pyroclastic Density Currents

Allocated presentation: Poster

Mass and Energy Exchange in Pyroclastic Density Currents: Development and Application of Physics-based Parameterizations

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Pyroclastic density currents encompass many fluid dynamic extremes from concentrated currents to dilute, turbulent flows. These currents are manifestly dynamic; spatial and temporal variability are an inevitable consequence gravity and momentum exchange. These exchange processes are crucial in determining runout, inundation area, deposit formation and ultimately the hazards of these currents. This presentation focuses on these momentum, mass and energy exchange rates using high resolution multiphase numerical simulations (MFIX) and comparison to large-scale experiments and observed PDC and deposits. We first validate the multiphase modeling through comparison to the PELE experiments and provide thermal energy, entrainment and mixing relationships. These parameterizations are compared to a compendium of experimental data for gravity currents. These parameterizations are appropriate for augmenting multilayer depth-averaged approaches and provide physics-based guidance for the demarcation between layers and the appropriate exchange terms. The mixing relationships presented are also useful for comparison to a range of thermal proxies. We next scale the multiphase simulation up to natural scale flows, specifically looking at the role of channelization and change in slope. Avulsion conditions are compared to flows from Tungurahua and Merapi. Finally, we consider the case of pyroclastic density currents encountering a water interface and compare the mixing zone dynamics of different scales of flows from small scale flows from Montserrat to larger scale dynamics relevant for Hunga Tonga. Particularly for the Hunga case we examine potential plunge conditions and the initial propagation of submarine currents in channels to examine propagation velocities and concentration gradients.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Talk [Invited]

Volcano-tectonic controls on the 3D architecture of sub-volcanic magma storage at Campi Flegrei, Italy

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Understanding pre-eruptive magma storage depth(s) is essential for the reliable interpretation of monitoring data at active volcanoes. While geophysical datasets provide important information about the current state of a volcanic system, petrological studies of historic eruptions are essential for determining variability in pre-eruptive conditions beneath long-lived centres. However, as petrological methods rely on pressure-dependent phase equilibria, they provide an inherently one-dimensional insight into magma accumulation depths with no lateral information. Such lateral information may be particularly important in large caldera systems such as Campi Flegrei (Naples, Italy) where recent (<15 kyr) eruptions have been dispersed across a large area, with vents located in diverse volcano-tectonic settings. Here, we present an overview of historic petrological and geophysical constraints on magma storage conditions at Campi Flegrei which reveal a complex multi-level magmatic system. We then use a novel machine learning-based clinopyroxene thermobarometric model to systematically supplement these with new high precision crystallisation depth estimates for post-15 kyr magmas erupted at vents across the caldera. By comparing the crystallisation depths of magmas erupted in different spatial locations, we identify lateral variations in magma storage conditions, gaining a three-dimensional picture of the sub-volcanic architecture which agrees with independent geophysical constraints. Importantly, our results show a difference in magma storage depths which correlates with volcano-tectonic setting, indicating a regional structural control on magma storage and evolution. Our results are important for volcano monitoring, suggesting that pre-eruptive activity in different parts of large volcanic systems might be characterised by distinct signs of unrest.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Talk

Temporal evolution for the last 75 years of unrest at Campi Flegrei caldera (Italy)

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The temporal interval between eruptive events can exceed human life, which poses great challenges for the management of volcanic crises. Campi Flegrei are an emblematic example of this complexity, with 350.000 people living inside the caldera and about two million people nearby. The last eruption took place in 1538 and a crisis of volcanic unrest is ongoing since 1950 and with documented episodes going back to Roman times. Periods of ground uplift, increased seismicity and enhanced release of magmatic gases are intercalated by episodes of subsidence and diminished seismicity (e.g. 1984-2005). While several mechanisms to explain these manifestations have been proposed, a quantitative framework is still missing. We use monitoring parameters and existing data in combination with thermal modelling and calculations of the physical properties of magma to provide plausible scenarios for the status of eventual magma in the shallow crust at Campi Flegrei. Here we show that the injection of magma at 4 km depth, as well as a flux of magmatic fluids from greater depths are both necessary to explain the measurements and observations collected since 1950. Our results show that potentially eruptible magma is present today at depth of about 4 km. However, its compressibility and the high temperature of the crust surrounding the reservoir leads to low magma overpressures within the reservoir. The first order constraints inferred by our calculations provide valuable insights to define scenarios for the evolution of the ongoing volcanic crisis.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Talk

Progress in anticipating crustal rupture during unrest at Campi Flegrei

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The 2017-2024 volcano-tectonic (VT) crisis at Campi Flegrei has provided a remarkable dataset for relating changes in VT seismicity with time to the progress of crustal rupture. The rate of VT seismicity passed through four stages until early 2024: an exponential increase in 2017-2020, a constant rate in 2020-2022, a hyperbolic increase until November 2023 and a three-month decay until March 2024. The sequence was followed by a rapid increase in rate to the highest recorded value in April 2024, since when it has been in gentle decline. Throughout the sequence, the floor of the caldera was uplifted at rates of 1-2 cm a month in the zone of fastest movement. An energy balance between uplift and seismicity reveals an accumulation of stress until 2022 and a decrease thereafter. The highest VT event rates thus occurred while stress was being lost. Such a relation is counter-intuitive, because decreasing stress is commonly associated with an Omori-style decline in VT event rate while crust relaxes. We attribute the increase in event rate to a self-accelerated interlinking of fractures that, more speculatively, triggered a temporary redistribution of pore fluids in the zone of nascent rupture, resulting in the brief decrease in seismicity in late 2023-early 2024. If confirmed, our interpretation suggests that Campi Flegrei's crust today contains a major new discontinuity – that is, a structural weakness now available to be exploited by magma or magmatic fluids during future episodes of uplift.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Talk

Monitoring the accelerating deformation and seismicity of the ongoing unrest of Campi Flegrei caldera (Italy)

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Since 2005, the Campi Flegrei caldera has exhibited progressive ground inflation and intensified seismic activity. Using monitoring data collected from 2000 to 2023, we analyzed the temporal trends in geophysical data and the relationships between them. Our results identified a decadal accelerating trend accompanied by oscillations of varying frequencies. A parabolic acceleration in vertical uplift, estimated at approximately 0.7–0.8 cm/yr^2, was observed at the center of the caldera (RITE GNSS station). Additionally, a super-exponential increase in the number of earthquakes was detected. The primary oscillation periods ranged from about 2 to 5 months (shorter periods) to approximately 1.5 and 3 years (longer periods). Data inspection revealed a temporal correlation between deformation rate and seismicity, along with a robust exponential relationship between ground deformation and the cumulative number of earthquakes. This relationship has shown an inflection since around 2021, characterized by an increase in its exponent and heightened sensitivity of seismic activity to caldera inflation. These findings were interpreted as evidences of quasi-elastic behavior in the upper crust and a stress memory effect, reflecting the reaching of a stress level larger than the peak observed during the 1982–84 crisis. As of the time of writing, the described trends continue to persist with similar characteristics. The exponential relationship between vertical uplift and cumulative earthquake numbers remains valid. The May 20, 2024, Md 4.4 event fully aligns with the hypothesized behavior, raising concerns about the potential for new seismic crises if the bradyseism persists with the same trends and relationships.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Talk

Imaging of volcano-tectonic features and plumbing system of the Campi Flegrei caldera by magnetotelluric survey

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Electromagnetic imaging can proficiently detect the volcano-tectonic features defining the structure of a Volcano. A magnetotelluric (MT) survey recently performed allowed to obtain a 3D tomography of the shallow and deep structure of the whole Campi Flegrei caldera (CFc). The resistivity image shows different anomalies at different scales resulting from the complex volcano-tectonic setting of the caldera, its plumbing system, the geothermal reservoirs, and the configuration of the plumbing and geothermal systems. The produced 3D resistivity imaging, dentified the electrical pattern of the investigated structure down to a depth of 20 km below sea level. Results have been interpreted considering the volcanological and petrological features available in the wide literature on the CFc. The electromagnetic reconstruction of the volcano's deep internal structure points out the configuration of the plumbing system and the main structures for the ascent of magma and magmatic fluids, at least below a large continental portion of the caldera. The preliminary obtained picture of the electrical resistivity distribution with depth suggests that the CF caldera plumbing system appears to be formed by distinct branches with a shallower geothermal system well developed below the Solfatara-Agnano area fed by a deeper source. The main fault system, acting as a preferential pathway for magmatic fluids, is also identified. Lateral variation of the anomaly also provide indication of the volcano tectonic features associated to the caldera collapse occurred at different scale. The resistivity model allows delineating major clues of the caldera's setting.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Talk

The Solfatara eruption of Campi Flegrei (Italy): combining field, textural and geochemical data to understand the dynamics of small-volume volcanic events at active calderas

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The 4.3 ka Solfatara eruption (Campi Flegrei, Italy) provides valuable insights into the eruption mechanisms and scenarios of small-volume explosive volcanic events at active calderas that host long-lived hydrothermal systems. In this study, we present results from the stratigraphic analysis of the Solfatara tephra deposits, alongside a detailed characterization of the physical, textural and chemical properties of the erupted juvenile products. The Solfatara deposit sequence is divided into two stratigraphic units, each corresponding to a distinct eruptive phase. Unit 1 predominantly consists of bedded ash deposits that exhibit clear signs of hydrothermal alteration. In contrast, Unit 2 is characterized by massive to cross-bedded ash deposits and by massive lapilli-bearing layers. The ash deposit extends up to approximately 10 km NE of the crater. Proximal outcrops include lithic-rich breccia deposits and ballistic shower beds, abundant in Unit 2. Component and textural analyses reveal that Unit 1 contains only 10–20% of dense to moderately vesicular juvenile glass, with the rest of the particles being hydrothermally altered lithics. In Unit 2, juvenile content ranges from 30% to >50%, with predominantly vesicular textures. The juvenile material has a homogeneous phonolitic-trachytic composition in both units, indicating that the eruption originated from a common magma batch. Overall, our findings suggest that Unit 1 formed during low-energy explosions primarily driven by fluid expansion within the hydrothermal system, with some contribution from the ascending magma. In contrast, Unit 2 formed during a phase characterized by multiple, transient events, including explosion breccia events, mainly driven by magma fragmentation.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Volcano-tectonic controls on magma evolution at Campi Flegrei, a long-lived caldera system

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Campi Flegrei volcano (Italy) is one of the most hazardous volcanoes on Earth, having produced >70 eruptions in the past 15 kyr and currently showing signs of unrest within a densely populated region. Eruptions in the last 15 kyr span a range of eruptive styles and compositions, broadly correlating with different spatial/structural locations of vents within the larger caldera system. Variability in glass O, Sr, Nd, and Pb isotope composition of erupted products also correlates with vent structural setting: eruptions along caldera rim faults have isotopic compositions which deviate further from typical mantle source values than those from the central or western caldera. Rhyolite-MELTS thermodynamic modelling allowed identification of intensive variables (pressure, water content, oxygen fugacity) which best reproduce the liquid line of descent of glass data from post-15 ka Campi Flegrei eruptions. Our results are consistent with previous studies in failing to fully reproduce the compositional diversity of Campi Flegrei magmas through fractional crystallisation alone, highlighting the important role of country rock assimilation. Isotopic variation between eruptions, outside the range expected for typical mantle-derived magmas evolving through fractional crystallisation, attests to variations in the amount/type of assimilated material. Comparison with potential basement rocks suggests Palaeozoic metamorphic basement is the likely contaminant of eruptions from caldera rim faults whereas syenitic restite likely contaminates central and western caldera eruptions. Our results demonstrate a link between vents' spatial/structural locations and processes operating within the magmatic system, suggesting magmatic evolution at long-lived caldera systems is inherently tied to the volcano-tectonic setting of vents.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Unveiling the Maddaloni/X-6 eruption as one of the major events in Campi Flegrei volcanic history

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A detailed reconstruction of the physical parameters (i.e., intensity and magnitude) and tempo of past explosive volcanism is pivotal for hazard assessment and risk mitigation. With this regard, the study of tephra layers recorded in proximal and distal successions provides a powerful tool for reconstructing the eruptive history of volcanoes. The Campi Flegrei caldera, Italy, is among the most productive volcanoes of the central Mediterranean area. However, the volcanic history preceding the M7.7-7.8 (VEI 7) Campanian Ignimbrite eruption (~40 ka) is still poorly constrained. Recently, one of the most widespread Late Pleistocene Mediterranean marker tephra (i.e., the marine X-6 layer), has been correlated to the Maddaloni fallout eruptive unit (~109 ka), previously described in proximal settings and ascribed to Campi Flegrei. Using a semi-analytical tephra dispersal model, we reconstructed the main eruption source parameters of this explosive event, thus characterising the ash dispersal as far as distal areas (~900 km). Our results suggest that the Maddaloni eruption was characterized by an early Plinian phase involving ~3-21 km^3 DRE of magma, followed by a co-ignimbrite phase, as large as 60-300 km^3 DRE, associated with large pyroclastic currents (up to ~70 km^3 DRE, likely related to a caldera collapse phase). This outcome ranks the Maddaloni/X-6 as a new high-magnitude (M7.6) eruption in the volcanic history of Campi Flegrei. This study provides new insights on the capability of the Campi Flegrei magmatic system to repeatedly generate very large explosive eruptions, which has huge implications for volcanic hazard assessment in the central Mediterranean region.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Geodetic Modelling of Ground Deformation at Campi Flegrei Caldera (Italy) During the 1985–2003 Subsidence Phase

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Campi Flegrei caldera, a 15 km-wide volcanic system located west of Naples, hosts nearly 400’000 people. Its last eruption took place in 1538 CE. The caldera experienced periods of unrest in the 1950s, 1970s, and 1980s, characterized by rapid uplift alternating with subsidence. The last unrest began in 2005 and is still ongoing, marked by ground uplift, increased seismicity, and high-flux gas emissions. The past and current unrest are matters of study and scientific debate. However, less attention has been dedicated to the subsidence phases, which, on the contrary, can give useful insights into the dynamics of the plumbing system. This study focuses on the subsidence phase following the ’80 unrest and preceding the current unrest. We present an unprecedented levelling dataset of hundreds of benchmarks measured with frequent campaigns. Data show a decreasing rate of subsidence velocity (max -1 m in Pozzuoli) and a normalized spatial pattern similar to the unrest phase. Geodetic modelling is conducted using the levelling time series, complemented by InSAR data from the ERS mission (1992–2003). A finite element model accounting for subsurface heterogeneity properties within the caldera is employed to analyze the deformation. By comparing these results with those from the current unrest phase, we assess whether the same two-source magmatic plumbing system, consisting of a shallower ellipsoid (4-6 km) and a deep sill (8 km) accounts for both subsidence and uplift phases. Understanding the mechanisms driving these contrasting deformation episodes is critical for interpreting the caldera’s long-term dynamics and assessing future volcanic hazards.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Continuous gravity recordings at Campi Flegrei caldera by means of spring and superconducting gravimeters

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We present the results of continuous gravity recordings collected at Campi Flegrei caldera (CFc). CFc is an active volcano in southern Italy, currently in a state of unrest characterised by ground deformation, seismic activity and fumarolic emissions. Since the 80's, periodic six-month time-lapse gravity surveys are carried out on a network of benchmarks for volcano monitoring. Due to the intensification of the unrest, in January 2023, a permanent gravity station, equipped with a gPhoneX spring gravimeter, was installed to complement the relative gravity surveys, allowing an improved temporal resolution. Thereafter, in October 2024, through a collaboration between INGV, DiSTAR and Institut Terre et Environnement de Strasbourg (ITES), a superconducting gravimeter (iGrav#029) was provided on loan and installed at Rione Terra, the most active sector of CFc, where the largest ground deformations occur. We report on processing and analyses performed to obtain reliable parameters for Earth and oceanic tides, non-tidal corrections, and gravity residuals for both gravimeters. Concerning the gPhoneX, due to the large instrumental drift, the latter was carefully analyzed, as it can hide elusive long-term gravity changes eventually caused by underground mass variations. For the iGrav#029, the focus was on the accurate calibration. It was carried out through multiple approaches, including synthetic tides, parallel measurements with an A10 absolute gravimeter and the gPhoneX. Always in view of catching elusive volcanic gravity signals, we examine in depth the relationship between gravity and atmospheric pressure changes both in time and frequency domain. Gravity signals are interpreted in light of the current dynamics at CFc.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Time gravity changes during the current unrest at Campi Flegrei caldera (Italy)

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Since 2005 Campi Flegrei caldera (CFc), Italy, is experiencing a new unrest episode, characterized by ground uplift rates exceeding 10 cm/yr, relevant seismicity and increased gas fluxes at Solfatara-Pisciarelli fumaroles. Geodetic, seismic and geochemical data point to an inflating source located at about 4 km depth, thought to be fed by hydrothermal fluids and/or magma originating from a deeper reservoir. Recent investigations on the nature of the source of the unrest (e.g., hydrothermal and/or magmatic) are mainly based on seismic tomography and joint ground deformation and petrological modelling, while gravity data, crucial to discriminate mass and density, have not been employed up to now. In this contribution we analyze the gravity changes occurred at the CFc in the last 10 years. In particular, we show the results from numerical modelling to obtain estimates on both mass and density variations at the source. From this analysis we suggest that a hybrid source, composed by a mixture of magma and fluids, is presently driving the unrest.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Weak crustal layer beneath Campi Flegrei caldera identified: what's its impact on unrest dynamics?

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Calderas unrests are often challenging to relate to magmatic or hydrothermal origin, which is a key question to improve the hazard assessment related to the unrest dynamics. Campi Flegrei is a clear example: since 2005 the caldera experienced accelerating ground uplift, seismicity rates, and degassing, and the origin of this unrest - whether magmatic or hydrothermal - remains a subject of debate. To better characterize the underground structures and link them with the current unrest dynamics, we conducted petrological and X-ray microtomography investigations on cored rocks from a ~3 km deep geothermal well located near the centre of caldera. Our laboratory results were complemented by a 3D high-resolution seismic tomography, and by numerical simulations of magma pathways below the caldera. At a depth of ~2.5 - 3.0 km we identified a transition to a weaker tuff layer. Such layer is likely to trap magmatic fluids and build up overpressure, causing the current deformation and seismicity. Our magmatic dyke pathway simulations indicate that the combination of the stress generated by caldera unloading, and the magma neutral buoyancy level, promotes the arrest of ascending dykes at such depth. This suggests that the weak tuff layer revealed by our observations may be the consequence of the accumulation of past intrusions which deformed, heated, and released magmatic fluids, deteriorating the surrounding rocks. This weak layer may play a crucial role in influencing the dynamics of recent unrests, and possible future magma ascent.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Reconstruction of the eruptive history Campi Flegrei caldera by means of the thermomechanical model

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We use the measured sequence of individual eruptive unit volumes V_i and their dates t_i at the CF caldera as the input dataset for calibrating a thermomechanical model that describes the formation and temporal evolution of a magma chamber through the incremental injection of hot basaltic dikes into cold crustal rocks (at 8-12 km depth). The model accounts for heat transfer between the magma and host rocks, solidification/melting diagrams, the displacement of the medium using an analytical solution for an elliptical crack in a homogeneous medium, and eruptions. We assume that an eruption occurs when the volume of interconnected magma with a crystallinity below a given threshold exceeds V_i. After the eruption, the system shrinks, and new magma begins to accumulate. We calibrate the parameters of the model to match the t_i-V_i sequence by varying the magma supply rate, the time of magmatism initiation, and the geometry of the injection zone. Good agreement with the measured data was obtained for a supply rate of 5.4 km^3/1,000 years. At this rate of magma injection, we estimate that today more than 43 km^3 of eruptible magma are present within the volcanic plumbing system from a total of about 650 km^3 of injected magma since 120 ka. Based on the distribution of rock density and melt fraction, we calculated synthetic seismic tomography (Vp and Vs distributions) of the CF caldera and compared it with present-day data.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Characterisation of the eruption magnitude distribution during the last three Epochs of activity of Campi Flegrei caldera (Italy)

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The Campi Flegrei caldera, located in southern Italy in the western part of the Bay of Naples, is an active and restless volcanic system. The caldera and its surroundings are densely populated, being one of the areas at highest volcanic risk on Earth. The last three Epochs of activity of Campi Flegrei caldera (< ~15 ky) have been marked by intense volcanism and ground deformation, with over 60 eruptions recorded. Despite extensive studies on some of its larger eruptions, the volumes of magma erupted during many of the Campi Flegrei events remain poorly constrained, mainly due to the limited quality and quantity of field data available, particularly for older eruptions. In this study, we apply a novel statistical method that estimates tephra fallout deposit volumes using thickness data from a minimum of two distinct sampling locations, such as one proximal and one distal. This approach offers a simplified yet reliable alternative for eruptions where field data are scarce, making it suitable for eruptions with incomplete records. As a result, we obtain the distribution of the volumes of several tephra fallout deposits along with the related uncertainties for each Epoch of activity. Using the published estimates of the density of tephra fallout deposits, we convert these volume estimates into mass estimates for each eruption and obtain the respective likely range of eruption magnitudes. Thus, this work contributes to a better understanding of Campi Flegrei caldera eruptive history, which is essential for a more robust hazard evaluation, risk mitigation and preparedness efforts.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Triggers mechanism and reservoir configuration preceding eruptions at Campi Flegrei

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The current unrest of Campi Flegrei caldera, Italy, which started in 2005 recently consisted of earthquake swarms and ground uplift of up to 20 mm/month. With 500,000 residents living in the red zone, it is essential to assess how the ongoing crisis will develop. Here, we use clinopyroxene-only thermobarometry based on supervised machine learning [1] on pyroclastic samples collected from the opening phase to the upper portion of the eruptive units from emblematic eruptions, varying in age, eruption style, and location within the caldera. Eruptions are all preceded by storage of magma at about 4 km depth and, in most cases, are also fed by hotter magma extracted from depths greater than 8 km. While some eruptions are likely triggered by the arrival of magma from depth, the trigger mechanism for other eruptions, especially the younger ones that occurred in the central sector (e.g., Santa Maria Delle Grazie, Solfatara), could be external to the magmatic system such as elastic crust weakening causing the arrival of magma from depth after the eruption begun. We find the shallowest recorded depths of magma emplacement to correspond to the current source of seismicity and deformation, and the greater depths to correspond to the deep reservoir highlighted by seismic and recent magnetotulleric surveys. This study provides insights on the preferred magma pathways potentially heralding a volcanic eruption, as well on the possible eruptive scenarios, which are crucial to consider for volcanic hazard management. [1] Ágreda-López et al. (2024) Computers & Geosciences, 193

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Uncovering fluid circulation dynamics in the Pisciarelli hydrothermal system (Campi Flegrei caldera, Italy) through numerical modelling

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The Pisciarelli fumarole field in the Campi Flegrei caldera (Italy) is one of the most active hydrothermal systems, with high CO_2 fluxes and significant seismicity. Since 2011, the area has experienced intense hydrothermal activity, including fumarole openings, groundwater level fluctuations in local springs, and mud emissions. Understanding the fluid dynamics and hazard potential of this system is essential for volcanic risk assessment. This study takes a comprehensive approach, integrating geophysical models and thermo-fluid dynamic numerical modelling to investigate the current state of the Pisciarelli hydrothermal system. We used high-resolution Electrical Resistivity Tomography (ERT), Time-Domain Induced Polarization (TDIP), and Self-Potential (SP) surveys to map subsurface structures such as fault systems and fracture zones, which are critical for understanding fluid migration pathways. Based on these data, we developed a conceptual model of the hydrothermal system and, thanks to constraints derived from various geological and geochemical literature studies, we performed numerical simulations using the TOUGH2 simulator and its EOS2 module, which models the fluid flow of an H_2O-CO_2 mixture through a porous medium. The simulations provided valuable insights into fluid ascent dynamics, highlighting the impact of permeability contrasts on fluid flows and their effect on pressure and temperature conditions within the system. The results also emphasized the role of fault systems in controlling fluid migration and surface degassing, clarifying the mechanisms responsible for the observed hydrothermal activity. This reconstruction improves our understanding of the system's fluid dynamics, paving the way for enhanced volcanic hazard forecasting and more effective monitoring strategies in the area.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Moment tensor inversion and waveform clustering for 10 years of seismicity at the Campi Flegrei volcanic complex, Italy

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Campi Flegrei (CF) is a volcanic system located in a densely populated area west of Naples, Southern Italy. With a long history of eruptions, CF is the largest active caldera system in Europe. The most prominent feature of CF activity is ground deformation (so-called ‘bradyseism’), which consists of rapid uplift usually accompanied by seismicity, followed by slow subsidence aseismic phases. The most recent awakening episode started almost 20 years ago, climaxing by mid 2024 with more than 1500 events / month, and largest magnitude Md = 4.4. In this work we analyze the seismic catalogue from the INGV-Osservatorio Vesuviano, from 2014 to 2024. For a selected subset of ~100 events with Md > 2.5, we perform time-domain, full-waveform Moment Tensor (MT) inversion using data recorded by up to 20 stations within 50 km epicentral range. The inversion is conducted using a probabilistic approach. Different velocity models and frequency bands are adopted for stations located within two distinct distance intervals. We obtain full, deviatoric and double-couple MT solutions for more than 80 events. From waveform similarity we identify 7 earthquake clusters, each characterized by similar locations and focal mechanisms. Most mechanisms indicate normal faulting; offshore events have locations and fault plane orientations which resemble the geometry of the caldera rim, while those in the most active Solfatara region mostly strike WSW-ENE. These results reveal with unprecedented detail the geometry and kinematics of the active fault structures in the Campi Flegrei region, and their relationships with volcano-tectonic lineaments.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

The space-time architecture variation of the shallow magmatic plumbing systems feeding the Campi Flegrei and Ischia volcanoes (Southern Italy) from halogen constraints

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Understanding the architecture of the magma plumbing system and the conditions of magma storage before an eruption is crucial for managing volcanic crises. This text uses chlorine as a geobarometer for potassic alkaline magmas at the Campi Flegrei volcanic complex to determine the depth of fluid-melt equilibration. The results from explosive eruption fallout deposits reveal multiple equilibration zones at different depths over time, including shallow magma storage. For various representative eruptions (Agnano Monte Spina, Pomici Principali, Astroni 6, and Monte Nuovo), pressure estimates range from 65 to 115 MPa. In comparison, the pressure for the Cretaio eruption (Ischia Island) is about 140 MPa. The pressures for the two largest eruptions, the Campanian Ignimbrite and the Neapolitan Yellow Tuff, show a shallow low-volume domain (~40 MPa) for the Plinian phase of the Campanian Ignimbrite and a deeper reservoir (~130–165 MPa) for the Neapolitan Yellow Tuff. These shallow pressures are interpreted as corresponding to transient magma apophyses, whose eruption was facilitated by tectonic stresses, crustal rheology, and volatile exsolution. The approach using chlorine to investigate volcanic plumbing systems is applicable to all alkali-rich magma systems.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Onland-offshore tectono-stratigraphic reconstruction of the Campi Flegrei caldera: deciphering the interplay between volcanism, deformation and collapse in the last 15 kyr

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Volcanic fields have a remarkable connection between structural features and volcanism. This is particularly enhanced by the presence of caldera structures, that tend to confine the spatial distribution of vents and control the sedimentation of primary pyroclastic and volcaniclastic sediments, especially in the case of partially submerged volcanoes. All these features accurately describe the volcano-tectonic evolution of the Campi Flegrei caldera (southern Italy). Here, through the integration of surface geology, reinterpretation of well-log data and offshore data we reconstructed the shallow tectono-stratigraphic architecture of the caldera. Using representative geological cross-sections we illustrate the main volcano-tectonic sectors characterized by the prevalence of pyroclastic and/or marine sediments, as well as the presence of volcanic vents, volcano-tectonic collapse, nested caldera structure and the central resurgent dome. The analysis of the main reference surface and their thickness show that the maximum marine ingression only partially involved the nested caldera, forming horseshoe branches to the east, south and west. The presence of the earliest monogenetic vents approximates the position of the neo-formed Neapolitan Yellow Tuff caldera. These inferred features are hindered by the activity of volcano-tectonic faults and younger volcanic activity. All features indicate a post-caldera deformation evolution characterized by a central resurgent dome and the coeval activity of faults, both along the rim and in the central sector. These results may represent the base for a comprehensive assessment of the structure of this volcanic area opening the way to a more accurate framework to interpret its dynamics.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

Electromagnetic monitoring of the Campi Flegrei active volcanic area

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The Campi Flegrei caldera in southern Italy is currently experiencing a prolonged period of intense unrest, characterised by significant degassing, rapid ground uplift, and increased seismicity. This activity is monitored using various methods, including seismic, gravimetric, ground deformation, geochemical and thermal analyses. However, electromagnetic monitoring within the caldera is lacking, despite its ability to provide a powerful means of investigating active volcanic areas by correlating electromagnetic variations with underlying hydrothermal and magmatic processes. These processes significantly affect the electromagnetic field, with fluctuations often reflecting changes in subsurface dynamics that can be measured and interpreted as related to magma movement and/or fluid circulation. Consequently, electromagnetic field monitoring is a critical tool for detecting and interpreting these variations, particularly during unrest phases, when rapid and significant shifts in volcanic behaviour require detailed analysis to enhance hazard assessment and early warning capabilities. In this study, we present a combination of continuous recording of natural electromagnetic signals with additional time-lapse electrical resistivity tomography performed in specific sectors of the caldera most involved in the geophysical and geochemical variations associated with the current unrest. These combined methods could provide new insights into the internal dynamics of the caldera, improving our ability to characterize and assess the ongoing volcanic activity of this complex volcanic system.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

First geophysical evidence of magma chamber beneath Campi Flegrei caldera through receiver functions analysis.

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The receiver function analysis (RF) is a well-established method to investigate the crustal and upper mantle structure. It is sensitive to seismic discontinuities and provides information about P and S-wave velocities. In this work, we study the crust and the upper mantle of Campi Flegrei Caldera (CFc) up to 50 km depth. The CF volcanic system has a complex plumbing system, possibly consisting of different sources. It is important to consider that the volcano has been showing, since decades ago, signs of unrest with episodes of ground deformation, degasification, and seismicity. We obtained the RF from thirteen stations using multi-taper deconvolution and we applied the transdimensional approach of Bodin et al. (2012) to determine 1D profiles of P and S-wave velocities and the probability of a discontinuity beneath each station. Although, we use petrological data to study the liquid fraction in our geophysical model. We observe a low-velocity zone beneath CF ranging from 8 to 16 km of depth with an extension of 4 x 5 x 12 km and a partial melt fraction up to 5%. Below the crust, we observe a low-velocity layer with a thickness of about 5 km. This layer dips southward, with its top located at a depth of about 16 km at the northernmost point and 23 at the southernmost. The melt fraction ranges from 15 to 30% within this layer. These results highlight for the first time the structure of the whole magmatic plumbing system at Campi Flegrei, from mantle to upper crust.

Theme: 3. Volcanic processes

Session 3.10: Multidisciplinary investigations into the structure and dynamics of Campi Flegrei caldera

Allocated presentation: Poster

High-frequency eruptive activity prior to the large eruption of the Neapolitan Yellow Tuff, Campi Flegrei, Italy.

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The Neapolitan Yellow Tuff eruption (NYT; 14.0 ka) is considered the last major eruption of the Campi Flegrei caldera (CFc; Italy), which formed a large caldera. After the NYT, volcanism resumed in three epochs with more than 60 eruptions, whereas volcanism before the NYT and after the Campanian Ignimbrite catastrophe is still poorly defined. At about 30 ka there was an eruption similar in volume to the NYT (Masseria del Monte) and later on a succession of pyroclastic deposits were deposited before the NYT. These deposits have been found in the peripheral area of the CFc and in some cores of distal records. However, it's still not clear how these eruptions occur in the proximal area and thus how to understand their eruptive dynamics. Here, we analysed new proximal outcrops and two new cores located >100 km from CFc, where it was possible to identify a number of eruptions prior to NYT. We found that at least five high-magnitude eruptions (~1km3) in a time span of <1 ka preceded the formation of the main NYT eruption. Many of these eruptions show a similar chemical composition to the NYT, suggesting a similar source or feeding system for the NYT. The ages also indicate a very short time span for this sequence of eruptions. This new finding may indicate that a series of eruptions can lead to the formation of a caldera, which is not necessarily associated with a single large catastrophic event.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Talk

Unravelling the eruption history of the Drammen Caldera: A multidisciplinary study of caldera-forming processes in the Permian Oslo Rift, Norway

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During the mature stages of the Permo-Carboniferous Oslo Rift, at least 15 calderas formed. Thick ignimbrite deposits are preserved in several of these calderas but remain poorly studied with modern methods. This study focuses on a rhyolitic ignimbrite succession in the 7x7 km Drammen Caldera, located 40 km southwest of Oslo. Here, we present field observations, petrographic results, and geochemical analyses of the deposits. Despite significant glacial erosion and partial Quaternary coverage, we show that over 450 m of ignimbrite stratigraphy is preserved in the Drammen Caldera. In addition, we have identified ashfall and lahar deposits interbedded between ignimbrite units. The ignimbrites range from high- to low-welding grade, and we interpret them to record at least five explosive eruptions resulting in two caldera collapse events. The ignimbrites are altered but retain primary volcanic textures. Cathodoluminescence (CL) reveals complex zoning patterns in quartz phenocrysts, indicating multiple growth and dissolution stages. Phenocrysts are heavily fragmented, with fractures healed by quartz cementation. Oxygen isotopes measured in-situ in zoned quartz phenocrysts suggest assimilation of high-$\delta^{18}O$ Lower Palaeozoic sedimentary rocks surrounding the caldera. Ongoing work on silicon isotopes and U-Pb geochronology aims to further refine the timing and petrogenetic processes. We conclude that the ignimbrites preserved in the Drammen Caldera hold information about complex magma reservoir dynamics, leading to several explosive eruptions. We present a six-stage evolution model for the caldera. This study highlights the potential for detailed multidisciplinary ignimbrite studies in other Oslo Rift calderas, as well as other eroded calderas globally.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Talk

Magma residence time of magma chambers at shallow crustal depths in past caldera eruptions in Japan

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In Japan, caldera volcanoes that can cause catastrophic eruptions are located in southern Kyushu, Hokkaido, and northern Tohoku. In volcanic hazard assessment for nuclear facilities, it is important to evaluate the activity potential of caldera volcanoes. In order to establish a method for evaluating it, we conducted material science studies focusing on the accumulation process of magma chambers as a preparation process for past caldera forming eruptions in Japan. The accumulation depth of magma reservoirs, magma accumulation time, and magma residence time just before eruption were estimated for the past active caldera volcanoes. These magma accumulation conditions were estimated using orthopyroxene, which is basically the same crystal. Magma accumulation time was also estimated by the U/Th method using ilmenite. As a result, it was estimated that the upper surface depth of magma chambers in the studied caldera volcano is 4 to 8 km, the crystal ages obtained by the elemental diffusion and U/Th methods are consistent with each other, and the magma accumulation time scales are long, ranging from several thousands to several tens of thousands of years. The residence time of magma chambers in the shallow crust was estimated to be at least several hundred to several thousand years. Based on the obtained information on the preparatory process of caldera eruptions, we propose a caldera activity assessment method for nuclear facilities on caldera volcanoes that combines geophysical surveys and eruption scenarios.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Talk

Timing and eruptive characteristics of the 349 ka Whakamaru supereruption sequence constrained by high-resolution analysis of tephra sites around New Zealand

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The Whakamaru supereruption from the central Taupō Volcanic Zone (TVZ), New Zealand, vented >1,500 km^3 of rhyolitic magma at ~349 ± 4 ka and is globally one of the largest Quaternary eruptions. The eruptive products include a complex sequence of welded ignimbrites in the central North Island, and tentatively correlated fall deposits of the same age, documented as the Rangitawa or Kohioawa tephras, found throughout New Zealand (including Chatham Island) and in distal marine cores in the Tasman Sea and South Pacific. The inter-relationships and relative timings of these deposits remain poorly constrained but are vital to understanding the nature and potential impacts of this event. Here, we present major and trace element data from Rangitawa/Kohioawa tephra collected from multiple sites at cm-scale resolution to characterise any spatial or temporal variability in glass compositions. Importantly, this work correlates fall deposits preserved in marine, terrestrial and lacustrine environments to one another over proximal, distal, and extremely distal areas. The presence and changing abundance of multiple glass populations in the fall deposits reflects the sequential tapping of multiple magma bodies through the eruption with no time breaks discernible. Extrapolated over multiple sites this approach will build a robust model of how the Whakamaru supereruption evolved, and the nature of ash dispersal across New Zealand and the South Pacific. Further to this work, the climate setting and post-eruptive environmental impacts are being examined through high-resolution pollen analyses at proximal and distal sites with drastic changes in vegetation assemblages observed across the tephra horizon.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Talk

Exploring the 2018 Kilauea Caldera Collapse with a New Benchmarked 3D Distinct Element Method Model

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When investigating volcanic unrest and eruptions, analytical and numerical solutions are useful tools in linking surface displacements to deformation sources at depth. These solutions, however, are limited by simulation of the host rock as an elastic or viscoelastic continuum. These material assumptions limit our ability to explore discontinuities such as fracturing and complex faulting, typical of caldera collapse events. By using 3D Distinct Element Method (DEM) Models one can simulate non-elastic (frictional-plastic) behaviour, as the breakage of elastic bonds between model elements allows for fracture localization, propagation and slip. To be confident to interpret our non-elastic behaviour, we must first benchmark our models against previous elastic solutions. We have therefore developed a 3D DEM model of a pressurised cavity within an initially linear-elastic, homogenous half-space, for which we can induce and under- or over-pressure. Surface displacements from this DEM model were benchmarked against the McTigue analytical solution and Finite Element Method (FEM) solutions without and with gravity. Benchmarking shows that all solutions fall within 10% of the analytical solution, with this difference decreasing with increasing depth, highlighting how a DEM model can yield reasonable displacements in the low strain, elastic phase of deformation. We use this newly benchmarked 3D gravity DEM model to forward model the chamber geometry of the 2018 Kilauea Caldera Collapse by analysing the surface displacement of the pre-collapse elastic deformation. Using this predicted chamber geometry, we then go one step further to model non-elastic deformation and explore the complex internal fracture geometries associated with the collapse

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Talk

Impact of the 2007 caldera collapse to eruptive variability at Piton de la Fournaise: insights from long-term satellite-retrieved effusion rate.

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Piton de la Fournaise volcano (La Réunion island, France) is one of the world's most active effusive volcanoes, averaging two eruptions per year. In April 2007, the collapse of the Dolomieu caldera was accompanied by its largest effusive eruption of the past century, with a bulk volume of approximately 240 Mm^3. This event temporarily altered the volcano's frequent effusive activity. We examine 24 years (2000–2023) of satellite thermal data from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) to analyze effusion rate trends for 37 eruptions before and after the collapse. Our reconstructed time series and evaluation of eruptive attributes, such as total lava volumes, eruption duration, and peak effusion rates, allowed us to identify five distinct eruption groups with differing characteristics. These groups underline the complex behaviors of the Piton de la Fournaise eruptions, challenging the traditional "pressure-cooker" model usually invoked for closed-vent basaltic volcanism. Furthermore, our analysis shows that while the long-term lava output rate has remained nearly constant (~0.7 m^3/s) over the last 24 years—suggesting a steady-state condition—the frequency and characteristics of eruptive groups shifted after the April 2007 caldera collapse. We propose that this collapse altered magma ascent from the shallow (upper crustal) system to the surface without affecting its overall rate. Long-term satellite-derived effusion rate assessments may improve our understanding of basaltic volcano dynamics and refine hazard assessments for frequently active volcanoes like the Piton de la Fournaise eruptions.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Talk

The rapid resurgence of the ice-covered Bárdarbunga after the 2014-2015 caldera collapse, evidence from repeated gravity surveys and other data

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Caldera collapses are relatively rare, with nine events documented globally over the last 100 years. Two of the most recent events, those of Kīlauea in 2018 and Bárðarbunga in 2014-2015 stand out in terms of the detailed observations and monitoring. In both cases the collapses were caused by lateral magma withdrawal from underneath the caldera. At Bárðarbunga, where the caldera is filled with up to 800 m thick ice, the collapse classifies as downsag, as ~2 km^3 of magma were drained laterally from underneath the caldera, causing the Holuhraun eruption, 40 km to the northeast. Maximum subsidence of 65 meters occurred in the northeast part of the caldera. Earthquake fault plane solutions in recent years and other observational data are consistent with resurgence at Bárðarbunga since 2015. To track possible changes following the collapse and quantify any resurgence, repeated gravity surveying has been carried out since 2015. The results show a large gravity increase within the caldera with peak amplitude exceeding 1 mGal. The shape of the anomaly that has been developing indicates maximum depth of source shallower than 1 km, placing it at the glacier-bedrock interface. The emergence and gradual growth of this anomaly indicates that the caldera floor has been rising, and that a significant part of the 2014-15 collapse has been reversed in only 8 years. These observations have implications for the understanding of how highly active basaltic calderas in rifting environments may operate, where resurgence occurs through upwards movement along the caldera faults.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Talk

Re-inflation at Askja caldera, Iceland, as seen by earthquake focal mechanisms

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Askja, an active basaltic caldera volcano in Iceland's Northern Volcanic Rift Zone, has exceeded 80 centimetres of uplift since August 2021, following several decades of ground surface subsidence. Modelling from the observed uplift suggests an inflating sill type source at around 3 km below the surface (Parks et al., 2024), and recent tomography work by Han et al (2024) images a shallow low velocity anomaly, both centred on the area of maximum uplift. In the same month that uplift began, there was also an overall increase in shallow microseismicity, which suggests a link between the cause of the surface deformation and the seismicity beneath Askja. To gain more insight into what is driving the seismicity beneath Askja, and how it may have changed with the onset of uplift, moment tensor solutions were constructed from a subset of events within the Askja caldera, both before and after the start of re-inflation, with the goal of uncovering any dominant earthquake slip orientation patterns. The Cambridge Volcano Seismology Group has maintained a dense seismic network surrounding and within Askja from 2007 to the present, which provides sufficient data to produce well constrained moment tensor solutions. Moment tensor solutions suggest that the direction of slip along faults encircling the innermost lake-filled caldera Öskjuvatn did not change when Askja switched from deflation to re-inflation. Results from this analysis will be presented, along with implications for our understanding of the behaviour of Askja's shallow magmatic plumbing system and its interaction with the caldera fault system.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Talk

Post-climatic evolution of supervolcanoes implicate significant volumes of residual mush remains after climactic eruptions.

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The architecture of silicic magma reservoirs underlying the Earth's largest and most explosive volcanoes has implications for the development of the continental crust, the volcano-plutonic relationship and volcanic hazards. Whereas significant attention has been paid to pre-climatic magma evolution and architecture, less is understood about the post-climactic magma reservoirs despite all the Earth's active supervolcanoes being in a state of post-climactic repose. The character of post-climactic eruptions at six supervolcanoes in the Central Andes reveal a family resemblance that indicates that significant volumes (100's to 1000's of km^3) of mushy climactic magma remained after the climactic eruption. At La Pacana, Guacha, Pastos Grandes, Panizos, Vilama and Cerro Galan calderas the post climactic eruptions are petrochemically similar to the dacitic climactic eruptions but are texturally more mature with extreme phenocrystal contents often exceeding 50%. In the context of resurgence at these calderas these eruptions are the result of magmatic rebound of residual mush although rare andesite implicates a role for deeper recharge from a regional reservoir. The spatial distribution and petrochemical character of these eruptions implicate local heterogeneity in otherwise homogenous caldera-scale mushes remaining after the climactic eruptions. Similar climactic - post-climactic relations have been identified at Toba caldera, Sumatra, where some of the eruptions are of subsolidus mush. These studies, along with others at Yellowstone and Valles connote that supervolcanoes are sites of significant volumes of unerupted residual mush that have implications for our understanding of volcano:plutonic ratios, the volume of pre-eruption magma reservoirs and their detectability.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Insights into Caldera Collapse Mechanics and Outstanding Questions from the 2018 Kīlauea Event

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The 2018 Kīlauea eruption provided unique constraints on caldera collapse. High-rate effusion decreased pressure within the magma reservoir, causing the shear stress on the ring fault to increase. Eventually, frictional resistance was overcome, leading to collapse, re-pressurization the underlying magma. Continuum models of ring-fault development (using Smooth Particle Hydrodynamics) are consistent with the inferred magma pressure drop at the onset of collapse. Extra-caldera GNSS and tilt data are consistent with abrupt co-collapse pressure increases followed by exponential decay due to magma outflow, *although the signature of faulting is difficult to isolate*. *Significant uncertainties in the summit magma storage geometry, including the role of a distinct "south caldera reservoir remain*. Volcano tectonic (VT) seismicity increased between collapses. GPS data from 2 sites (CALS, NPIT) within the caldera subsided proportional to cumulative seismicity counts. This strongly suggest that most VT seismicity was driven by creep and/or distributed shear. *However, VT seismicity is not completely localized, and first-motions inconsistent with double-couple sources*. Seismicity was concentrated on newer ring-fault segments, suggesting fault roughness was important. Seismicity rate, and the relative frequency of large VTs increased dramatically in the minutes before collapses. Inter-collapse subsidence at CALS & NPIT is consistent with rate-strengthening friction, but VTs and VLP nucleation require unstable friction. This implies heterogeneities and high-speed fault weakening during collapses. The final collapse cycle started unremarkably, although with a relatively low seismicity. *Whether the end of the eruption resulted from changes in the magmatic system, or the fault system is not settled*.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

GeoNet observations during the 2022-23 unrest episode at Taupō caldera volcano, Aotearoa New Zealand

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Lake Taupō in the North Island of Aotearoa New Zealand hosts a large caldera volcano that most recently erupted ~1800 years ago. The volcano has experienced ~16 unrest episodes since 1872. In May 2022 the volcano entered a new episode with increased earthquake activity and ground deformation. This episode was notable for two reasons: (1) the Volcanic Alert Level for Taupō was raised to 1 for the first time, and (2) a M5.7 on 30th November 2022 was accompanied by a small tsunami in the lake. Here we give an overview of seismic, geodetic, and tsunami observations during the unrest and what was inferred to have occurred during the unrest. Over 1780 earthquakes were detected beneath the lake over 13 months, the highest number recorded during instrumented unrest episodes at the volcano. Four distinct activity phases were identified, with earthquake relocations showing that the activity was focussed on overlapping caldera structures beneath the lake. A rapid 50 mm/yr inflation was detected within the lake, peaking during the M5.7 earthquake with 18 cm uplift and 25 cm horizontal movement recorded. GNSS data modelling suggested the inflation source was located at 4-8 km depth beneath the lake. Analysis of relative water-level gauge and survey data indicated the lake tsunami was generated by two sources: a sub-lacustrine landslide near the town of Taupō, and the rapid upward movement of the lakebed. Altogether, we suggest the 2022-23 Taupō unrest episode was caused by a new intrusion of magma at depth.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Small scale caldera collapse - A numerical study on central vent caldera-foming eruptions

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Large-scale magmatic systems are commonly associated with catastrophic caldera-forming eruptions. These events are generally linked to faults or eruption channels located at the periphery of the magma chamber, resulting in a caldera that reflects the full spatial extent of the reservoir. However, the dynamics of small to intermediate -scale magmatic systems that have also hosted caldera-forming eruptions, such as Krakatau (Indonesia) or Crater Lake (USA), are comparatively less explored. In these instances, the eruption is generally assumed to have begun from a single central vent of a volcanic edifice rather than through a ring fault system. In this study, we utilise a multi-physics numerical modelling approach to investigate the mechanics of central vent eruptions on the collapse stage. The interactions between magma dynamics, far-field tectonic stresses and non-linear visco-elasto-plastic rheologies are examined using the thermo-mechanical geodynamic code *JustRelax.jl*, in order to investigate the potential for roof failure above a shallow magma chamber. The models incorporate a thermally active magma chamber with variable geometries, connected to the volcanic edifice via a conduit structure. This framework allows the simulation of upward magma flow and the progressive depletion of the chamber, thereby providing insights into the processes governing central vent-driven caldera formation. Here we present a systematic parameter study on the driving forces behind this type of caldera collapse.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Geodetic and seismic moment calculations for caldera collapse events

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Calderas form when a magma chamber is emptied (either fully or partially), causing the roof to collapse into itself. In a piston style collapse, a mass in the middle of the structure subsides as a single block. This has been inferred by using seismic and geodetic methods during caldera-forming events. In the case that the piston is entirely frictional, the observed geodetic and seismic moments should be equal. If the geodetic moment is larger, this indicates some amount of aseismic (ductile) deformation, and the collapse is not entirely frictional; if the seismic moment is larger, this indicates incorrect or missing information in the final moment calculations. Using literature review and recalculations based on values cited in past studies, we compared geodetic and seismic moments for 8 caldera collapse events. The moment values generally fall above a 1:1 line when the logarithms of geodetic and seismic moments are plotted against each other, meaning that for these events, the geodetic moment is larger than the seismic moment. This implies some ductile (aseismic) deformation along with the existing brittle deformation during the collapses. These results may be used to determine how the discrepancy in depth to chamber and bulk shear modulus relate to gaps in seismic and geodetic moment calculations.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Time gap during VEI>6 caldera-forming eruptions: constraint from paleomagnetic directions for preceding airfall and following ignimbrite

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Recent paleomagnetic studies have proposed durations of some VEI>6 caldera-forming eruptions were longer than previously thought. These estimates are based on angular difference of paleomagnetic directions from the deposits and changing rate of geomagnetic secular variation (GSV). Here, we review these results with focusing on a pair of preceding airfall and overlying flow. Mean paleomagnetic directions (MPDs) of these deposits were well-determined (α-95<3°) by improved sampling techniques. Paleomagnetism from marine cores and present observations indicate the GSV change rate as 0.01°~0.1°/year. Therefore, time resolution of this method is “decades”. Datasets were compiled for nine caldera-forming eruptions. In three cases (Taupo/Mashu/Aira), the MPDs between fall and flow are indistinguishable (α-95 overlap) suggesting no time gap more than decades. In six cases (Kikai/Kp1/Shikotsu/Mamaku/HRT/FCT), the angular difference of MDPs for the fall/flow is 7° to 15°, and applying the fastest GSV (0.1°/year), the time difference estimates as 70 to 150 years. Recent (Holocene) and smaller (VEI=6) eruptions (Taupo/Mashu) show no significant time gap between the fall/flow. The historical records and observations indicate a stable Plinian column provides a fall, and eventually the column collapses for generating a flow. In this case, the two MPDs will be indistinguishable. While, Druitt&Sparks (1985) proposed “1st overpressure stage (providing fall+small flow)” and “2nd caldera-collapse stage (generating ignimbrite)”. Applying our data to this model, catastrophic caldera-forming eruptions could require a considerable time break after preceding Plinian eruptions. Our next challenge is petrologically detecting decades difference of magma residence time between the fall and flow.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Effects of regional stress state and pore fluid pressure on the onset and style of caldera collapse

Matías A. Villarroel*[a, b], Martin P.J. Schöpfer[c], John Browning[a,d], Eoghan P. Holohan[b], Claire E. Harnett[b], Carlos J. Marquardt[a,d], Pamela P. Jara[e]

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Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Computer vision geodesy and simulations of caldera collapse cycles at Kīlauea

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A growing number of basaltic caldera collapse observations have demonstrated the fundamental couplings between collapse and eruption dynamics. For example, every recent collapse has occurred via a sequence of large earthquakes that repressurize magma reservoirs, suggesting that a delicate balance between fault friction and effusion rate controls eruption progression. However, limited data have been available to resolve important factors such as fault slip distributions and inelastic rock deformation. A three-month-long eruption at Kīlauea in 2018 provided the best monitored collapse, with caldera subsidence captured by two GNSS stations and several digital elevation models from overflights. We obtain further resolution by creating a 'video geodesy' dataset with continuous imagery collected by the Hawaiian Volcano Observatory from multiple cameras on the caldera rim. We compute ground deformation by using optical flow methods to track feature movement over time and then projecting pixel offsets into 3D models. This gives both broad spatial coverage and high sample rates. We resolve vertical and horizontal displacements across the caldera on scales from 0.1-10 m. The imagery helps constrain ring fault slip distributions during and between collapse earthquakes, and provides preliminary evidence for significant off-fault inelastic deformation between collapse events. We compare these data with caldera collapse earthquake cycle simulations to infer rock rheology and ring fault properties, with the aim of revealing how large amounts of caldera subsidence between earthquakes relates to fault friction. This work thus shows the utility of webcam imagery for deformation monitoring and provides insights into caldera collapse eruption mechanics.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Reconstruction of the pre-caldera-forming phase during the 7.3 ka eruption at the Kikai Caldera (Akahoya eruption) based on geological analyses and plume modeling

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In many catastrophic caldera-forming eruptions (CFEs), Plinian eruptions often precede the climactic phases characterized by caldera collapse and the formation of large-scale pyroclastic density currents (PDCs). It is considered that such a preceding eruption triggers caldera collapse due to the decompression of the magma reservoir. Therefore, estimating the eruption conditions during the pre-caldera-forming Plinian phases is crucial for understanding the mechanism of CFEs. In this study, we focus on the 7.3 ka CFE (Akahoya eruption) at the Kikai Caldera, Japan, and discuss the eruption sequence and condition of the pre-caldera-forming phase through geological survey and plume modeling. The pre-caldera-forming deposits of the Akahoya eruption are divided into three units. The lower unit comprises a small ash fall layer. The middle unit comprises a Plinian fall deposit and a PDC deposit. The upper unit includes multiple Plinian fall deposits, PDC deposits, and co-PDC ash layers. The bulk volumes and mass discharge rates for each event are estimated as follows: Lower unit: 10^{-3}–10^{-2} km^3, Middle unit: 10^{-1}–10^{0} km^3, 10^{7}–10^{8} kg/s, and Upper unit: 10^{0}–10^{1} km^3, 10^{8}–10^{9} kg/s. These results indicate that the pre-caldera-forming phase of the Akahoya eruption began as a small-moderate explosive eruption, transitioned into a Plinian eruption and small-scale PDCs, and culminated into a large-scale Plinian eruption with sustained partial column collapses and intraplinian PDCs. This presentation will also discuss the mechanism of the subsequent caldera collapse from the estimated parameters of the pre-caldera-forming phase.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Variation of the magma chamber decompression and scale of precursory eruption for caldera-forming eruptions

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The processes of magma chamber decompression leading to caldera collapse are studied using two VEI 7-class caldera-forming eruptions from Aira and Kikai calderas in southwestern Japan to test the thresholds of magma chamber decompression for caldera fault activation. Petrological evidence suggests that the depth to the magma chamber is deep (~6 km) for Aira and shallow (~3 km) for Kikai. Water contents in phenocryst glass embayments indicate that Aira experienced a large magmatic decompression before the onset of caldera collapse, whereas caldera collapse occurred at a relatively low decompression at Kikai. The volume of magma erupted during the precursory Plinian eruptive phase is large (~40 km^3 DRE) for Aira and small (<10 km^3 DRE) for Kikai. Our friction models for caldera faults show that the decompression required to collapse a magma chamber is proportional to the square of the depth to the magma chamber for calderas of the same horizontal size. Lower friction on the caldera faults also causes the caldera to collapse at smaller decompression. This model can explain the variations in magma chamber decompression for the onset of caldera collapse, and also the difference in volume ratio between the magma that erupted in the initial Plinian phase before collapse and the magma that erupted in the main ignimbrite phase after the onset of collapse.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Reservoir reconstruction at Torfajökull volcano after the Thórsmörk super-eruption, identified through zircon age distribution and mineral chemistry

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Torfajökull is a rhyolite-dominated volcanic system at the edge of the active Eastern rift zone in Iceland's Southern Highlands. This highly geothermally active system has long been speculated to have experienced at least one caldera-forming eruption, based on its central topographic depression, dipping sediment features, and surrounding large tuyas, known as "Ring-fracture rhyolites". Additionally, an ash layer found in a Greenlandic ice core and marine sediments (North Atlantic Ash Zone II) is thought to originate from Torfajökull due to its distinctive glass chemistry, which also matches an ignimbrite deposit called "Thórsmörk Ignimbrite", located about 30 km south of Torfajökull. To test the connection between the Thórsmörk ignimbrite and a catastrophic event at Torfajökull, we examine zircon crystallization timescales and differentiation trends in mineral chemistry, building on previous evidence from field observation and glass chemistry correlation. U-Th crystallization ages (N > 1000) from a large suite of samples (N = 34) collected across Torfajökull, including the Thórsmörk ignimbrite, reveal a notable decline in zircon crystallization frequency around the time of the ignimbrite's emplacement. Zircon crystallization ages in younger units are limited to the post-Thórsmörk period, suggesting a complete reorganization of the subvolcanic magma reservoir. These observations strongly indicate a high-intensity eruption, which significantly emptied the upper crustal reservoir and was followed by a prolonged reconstruction stage. Mineral chemistry, particularly of Fe-Ti oxide and clinopyroxene, supports this interpretation, showing increased differentiation leading up to the Thórsmörk eruption, followed by less evolved and more compositionally heterogeneous units with increasing influence of mafic recharge.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Caldera-Forming Eruptions at Basaltic Volcanoes: Outcomes from the 2025 AGU Chapman Conference in Hilo, Hawaiʻi

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Basaltic caldera-forming rift eruptions represent an underappreciated hazard for many global communities, but also present an opportunity to better understand some of Earth's most active volcanoes. A handful of these eruptions have been documented globally in the last half-century, including at Miyakejima (Japan), Piton de la Fournaise (La Réunion, France), Bárðarbunga (Iceland), and most recently at Kīlauea (Hawai'i, USA) in 2018. Observations from Kīlauea and other global historical eruptions offer an unprecedented opportunity to understand calderas and associated rift systems and the dynamics of their interplay, but an international, community-driven synthesis has been lacking and numerous fundamental scientific questions remain. In February 2025, more than 120 researchers from around the world met in Hilo, Hawaiʻi, to establish our current state of knowledge, compare global caldera-rift systems, and map out work on critical outstanding questions. Technical meeting themes included lessons from historical eruptions; inferences into coupled magmatic-tectonic caldera-rift systems; eruptive processes, hazards, and forecasting; and the post-collapse evolution of caldera-rift systems. Additional activities included two field trips and several workshops. This presentation will summarize key meeting themes and new efforts arising from discussions in Hilo. We hope these efforts will bear fruit when the next large basaltic caldera collapse takes place somewhere on Earth.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

The caldera-forming eruption of the Tufo Rosso a Scorie Nere (RNR): insight from geological fieldwork and geochemistry

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The Tyrrhenian margin of Italy is the site since the Quaternary of intense K-alkaline magmatism. Several intermediate to large volume caldera-forming eruptions have occurred from nine caldera systems. The Sabatini Volcanic District hosts two calderas, the Bracciano and the Sacrofano calderas, which generated large ignimbrites. The largest of these eruptions issued from the Bracciano caldera and emplaced the Tufo Rosso a Scorie Nere ignimbrite (RNR), dated ca. 452 ka and associated with the first caldera-forming event of the district. The new geological mapping of the RNR ignimbrite allows us to quantify the erupted bulk volume calculated at 223 km^3 (138 km^3 DRE), which makes this a VEI6 eruption and the second of the Roman Magmatic Province after the 600 km^3(265 km^3 DRE) of the 39 ka Campanian Ignimbrite from Campi Flegrei caldera. Geochemical characterization of the glass allows us to test the efficiency of the residual glass geobarometry analysis with rhyolite-MELTs, and discuss the geometry and structure of the plumbing system leading to the RNR caldera-forming event.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

A thick lithic gravel-sand bed buried deep inside Santorini caldera, and its possible relationship to caldera flooding. IODP Expedition 398 Hellenic Arc Volcanic Field

Tim Druitt*[1], Sarah Beethe[2], Natasha Keeley[3], Charlie Wallace[4], Abigail Metcalfe[1], Katharina Pank[5], Jonas Preine[6], Sofia Della Sala[4], David Pyle[4], Ralf Gertisser[3], Steffen Kutterolf[5], Olga Koukousioura[7], Paraskevi Polymenakou[8], and IODP Expedition 398 scientists

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The post-collapse histories of ignimbrite calderas, and the onsets of new caldera cycles, are often masked by thick intracaldera fills. IODP Expedition 398 deep-drilled the fill of the marine Santorini caldera, penetrating up to 125 m below the sea floor, and terminating just above the seismically imaged acoustic ‘basement’ interpreted as intracaldera tuff from the 3.6 ka Minoan eruption. Drilling took place at four drill sites, two in the southern caldera basin and two in the northern basin, the deepest penetration being attained in the south (Site U1595). The lowermost unit penetrated is a pumiceous sand overlain by highly oxidized scoria (Unit L5). This is overlain by up to 35 m of lithic gravels that grade upwards into lithic sands (Unit L4). Tephra layers from the nascent intracaldera Kameni Volcano are vaguely defined in the upper levels of the L4 sands, but become better defined upwards, forming an ~8 m thick layer of stacked tephra layers (Unit L3). This is directly overlain by a 30 m thick pumice layer from the 726 CE eruption of Kameni volcano (Unit L2), then in turn by tephra from historical Kameni eruptions (Unit L1). In this presentation, we characterize the layer of gravels and sands between 100 and 65 m below the sea floor (Unit 4), both sedimentologically and petrologically. Along with biostratigraphic, paleo-botanic, and seismic stratigraphy constraints, we test the hypothesis of Nomikou et al. (2016) that Santorini caldera underwent catastrophic flooding following the Minoan eruption, and if so when.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Role of External Processes in the Initiation and Modulation of Explosive Volcanism at Christiana-Santorini-Kolumbo. IODP Expedition 398 Hellenic Arc Volcanic Field

Abigail Metcalfe*[1], Tim Druitt[1], Katharina Pank[2], Steffen Kutterolf[2], Jonas Preine[3], Christian Hübscher[4], Paraskevi Nomikou[5] and IODP Expedition 398 Participants

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Large polygenetic volcanoes can produce catastrophic explosive eruptions with significant societal and environmental impacts. The drivers of such eruptions include interactions and feedbacks between internal magmatic processes and far-field tectonic stresses. Such processes operate on overlapping timescales, obscuring their relative contributions. IODP Expedition 398 deep-drilled the rift basin volcano-sedimentary fills around the Christiana-Santorini-Kolumbo Volcanic Field (CSKVF) in the South Aegean Volcanic Arc, in order to unravel volcano-tectonic links. Using major and trace element analyses of volcanic glass shards from marine tephras and the CSKVF onland record, we produce a high-resolution chronostratigraphy of the rift basins. The existing seismic stratigraphy allows us to correlate major eruption deposits to onlap surfaces. Calculation of the basin subsidence history allows us to recognize the contribution of multiple factors in the initiation and driving of volcanism at the CSKVF. Lithospheric rifting NE of Santorini began >2 Ma, and ultimately triggered a period of sustained caldera-forming explosive volcanism starting at ~250 ka (the Thera Pyroclastic Formation). At the CSKVF, rifting is inferred to have modulated the internal magmatic processes by increasing the flux of mantle-derived melts, fluids and heat into the crust. This unique dataset provides new insights into the volcanic history of the CSKVF and has implications for understanding volcanic processes at other rifted arcs.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

High-Resolution Microseismicity Provides Insights into Ring-Fault Geometry at the Re-inflating Bárðarbunga Caldera, Iceland

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In 2014-15, the subglacial Bárðarbunga caldera collapsed, subsiding 65 metres as magma flowed out from beneath it to feed a fissure eruption at Holuhraun. Subsequently, the caldera has been re-inflating, indicating recharge of the crustal magma reservoir. Sustained seismicity along the caldera ring faults – but with reversed focal mechanism polarity compared to the eruption period – further supports its ongoing resurgence. Between June-August 2021 and May-September 2024 we installed broadband seismic arrays on the ice cap above Bárðarbunga, to improve constraints on earthquake hypocentres and focal mechanisms. We use QuakeMigrate to produce catalogues of microseismicity, with 8,500 and 19,500 events located in the campaigns in 2021 and 2024, respectively. The magnitude of completeness is ~ -1. Relative relocation reveals a sharply defined ring fault, consistent in geometry with geodetic constraints obtained during the 2014-15 collapse, thus providing strong evidence that the same structure is being reactivated as the caldera re-inflates. Tightly constrained focal mechanisms show excellent agreement with the local ring-fault geometry defined by the relocated microseismicity, and steep dip-slip faulting corresponding to uplift of the caldera floor. Low frequency earthquakes observed between 15 - 25 km depth in the normally ductile part of the crust below Bárðarbunga, and at around 6 km depth below the caldera, signify activity in the deeper plumbing system of the volcano, which may indicate magma ascent pathways. These events contribute to excellent ray coverage for tomography, which we will use to image the shallow melt reservoir and its geometry relative to the ring-fault.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

The role of local tectonic forces on magma chamber growth

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Silicic systems can grow to enormous volumes and produce devastating caldera-forming eruptions with major impacts on local to global scales. Their magma reservoirs are typically built incrementally from intrusions over prolonged timescales (often $>10^5$ years), influenced by parameters such as magma supply rates and volatile contents, as well as crustal properties. However, the role of local tectonic forces on the growth dynamics of large upper crustal magma bodies remains debated. To identify the impacts of regional extension and compression on the accumulation of large-scale magma chambers, we expand the Degruyter and Huber (2014) thermo-mechanical magma chamber model by incorporating local tectonic forces. We additionally vary parameters such as magma chamber volume and depth, volatile contents, and recharge rates to explore how these parameters affect the sensitivity of magma chambers to tectonic forcing. Our results suggest that local tectonic forces influence magma chamber growth only under extreme conditions involving extension or compression rates of $\pm 10^4$ Pa/yr or higher. Under these conditions, local extension causes a drop in eruption frequency especially in volatile-rich systems, while compressional forces tend to produce more frequent eruptions. Such decreased eruption frequencies under extension allow magma chambers to grow larger between eruptions, yet eruptions are typically also more voluminous, leading to magma chamber shrinkage after multiple eruption cycles. These findings deliver new insights into the role of local tectonic forces in magma chamber growth by influencing eruption frequency and magnitude. Understanding these dynamics is critical for identifying volcanic systems with the potential to grow to extreme sizes.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Rejuvenation of the Kos-Nisyros-Yali magmatic system after the caldera collapse events on Nisyros

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Caldera–forming eruptions rank among Earth's most catastrophic volcanic events, but despite the danger they pose, they are not yet fully understood. They are believed to follow recurrent evolutionary paths, called caldera cycles, comprising multiple stages. The focus of this presentation is the stage following a caldera collapse event, which can either lead to the rejuvenation or death of a system. Kos-Nisyros-Yali is the largest active magmatic system in the Aegean Sea, which underwent several caldera collapses, including a major catastrophic event at 161 ka. Here, attention is given to the latest caldera-forming event in this system, namely the Upper Pumice eruption on Nisyros at 58.4±2.7 ka. Roughly simultaneously to the rhyolitic Upper Pumice eruption, a relatively dry and hot andesite lava (~1050±30◦C), pre-eruptively stored at upper crustal conditions, erupted outside the Nisyros volcano, forming the small island of Agios Antonios at 59.7±6.5 ka (ulvospinel-ilmenite U-Th dating). The lava is more primitive than the contemporaneous units on Nisyros-Yali, resembling their recharge enclaves. This suggests that the latest caldera-collapse on Nisyros is associated with the voluminous effusion of recharge magmas, and thus indicates that after the caldera-collapse event, the upper-crustal silicic mush was rejuvenated. The influx of recharge magmas led to the formation of a second eruptible magma chamber, feeding the younger Yali volcano, its zircon and ulvospinel crystallization timescales being distinct from those of Nisyros (younger than the andesitic lava). This is supported by crystallization timescales determined in an explosive unit on Agios Antonios and in the other Yali units.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Reconstruction of the 13.1 Ma large volume caldera-forming SAU eruption in the northeast Pannonian Basin: a case of silicic volcanism at the latest stage of subduction.

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The late stage of Miocene silicic volcanism occurred in the easternmost part of the Pannonian Basin (eastern-central Europe), following the syn-extensional ignimbrite flare-up event (18.1–14.4 Ma). The formation of andesite-dacite-rhyolite volcanic field in the Tokaj Mts. took place close to the presumed retreating subduction zone which contributed to the back-arc extension of the Pannonian Basin. Four silicic explosive events were recognized here, the largest one was the rhyolitic, SAU (13.1 Ma) eruption. A >500 m thick volcaniclastic succession on the eastern margin of the Tokaj Mts fills the proximal part of the caldera and contains abundant basement-derived lithics. The boreholes also revealed a preserved section of the collapsed caldera-wall. Thorough hydrothermal activity (silicification, zeolitic, and argillic alteration) modified significantly the associated deposits. However, detailed zircon geochronology and trace element geochemistry integrated with glass major and trace element geochemistry of rare fresh samples revealed the unique fingerprint of this eruption. Many sporadic pyroclastic deposits measuring several tens of meters in thickness have been identified up to 100 km from the eruption center (e.g. East Slovakian Basin). Distal tuffs in Romania were also correlated to this eruption. This implies a large, caldera-forming eruption with a VEI=7 size. The remarkably heterogeneous and evolved trace element composition suggests evacuation of several silicic melt lenses from a large silicic magma reservoir. **Acknowledgements.** Funds: National Research, Development and Innovation Office (No. 145905); MTA–HUN-REN CSFK Lendület “Momentum” PannonianVolcano Research Group; The Ministry of Education, Science, Research and Sport of the Slovak Republic: VEGA-1/0526/21, and APVV-23-0227

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Structural and temporal analysis of a caldera collapse using high-resolution drone imagery: Askja volcano, central Iceland.

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Volcanism in Iceland is expressed by volcanic systems, constituted by fissure swarms and the related central volcanoes, often in the form of calderas. The structural interaction between regional rift faults and caldera structures plays a critical role in controlling volcano morphology, fluid circulation, and volcano flank stability. However, this interaction and the related volcano tectonic processes in time remain poorly studied. We used high-resolution digital elevation models (DEMs) and orthophotos derived from drone imagery to map and analyze ~4400 volcanic and tectonic structures along the eastern wall of the Öskjuvatn caldera. This caldera is the most recent at Askja central volcano, formed in 1875 during a Plinian eruption. The structural analysis was complemented by field observations collected in August 2023 and by 3D modeling to enhance spatial and structural interpretations. Our analysis focuses on the 1875 collapse sequence that shaped the current Öskjuvatn caldera wall, with major N130° collapse faults concentrated in the northeast that are nowadays inactive. Also, to the southeast, we mapped in detail a large landslide that occurred in 2014, displaying a general N030° fracture direction with active landslides and intense hydrothermal activity. Therefore, this cliff is characterized by concentric fracture systems that contrast with long lived rift-related faults that cross-cut the Eastern portion of the caldera wall with N030° trend. We suggest that the coalescence of these fracture sets is a critical factor in the caldera's collapse history, current morphology, and ongoing hydrothermal and gravitational activity.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Outline of the 2022-2024 eruption at Ioto Island (Iwo-jima), Ogasawara, Japan : small subaqueous eruption associated with shallow magma intrusion towards theof caldera floor

Masashi Nagai*[1], Takahiro Miwa[1], Setsuya Nakada[1], Hideki Ueda[1], Hirochika Sumino[2], Atsushi Yasuda[3], Tomofumi Kozono[1], Takashi Hirose[4], Hiroki Minami[5] and Tetsuo Kobayashi[6]

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Ioto Island is an active caldera volcano located in the Izu-Bonin-Mariana arc. Active uplift has continued since about 2011, suggesting that a shallow ring intrusioncontinues. From July 2022 to 2024, magma reached the seafloor off the coast of Okina-hama, resulting in frequent Surtseyan eruptions. While most eruptions occurred below sea level, a series of intense eruptions from late October to late November 2023 formed a new island. During this period, subaerial lava effusion accompanied by Vulcanian-like eruptions occurred briefly. The estimated eruption rate was relatively high at around 10^3 kg/s during island formation, compared to less than 10^2 kg/s during other periods. The whole-rock chemical composition of the essential materials was consistent, with a trachyte composition of about SiO_2 = 61.3 wt%. The composition of quenched volcanic glass was in the range of SiO_2 = 61.8-64.0 wt%, which tended to be low at the period of island formation. The eruption off Okina-hama, although small, showed a typical progression of shallow-water magma eruption. The estimated total erupted volume was only about 500,000 m^3. Obvious crustal deformation, such as deflation, associated with the eruption was not detected. Therefore, the magma ascending to the shallow subsurface of the caldera was hardly consumed by the eruptions and continues to accumulate below. Temporal changes in the composition of volcanic glass indicate that crystallinity was lower when magma was erupted at higher rates. Under off Okina-hama conditions, monitoring the composition of volcanic glass in ejecta may allow us to estimate transitions in eruption rates.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Water column survey and structural analysis at the Öskjuvatn lake during a caldera unrest (Askja, central Iceland)

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The lake Öskjuvatn is in the Askja caldera system (central Iceland). It originated from the Öskjuvatn caldera formation following the 1875 Plinian eruption. Since 2021, an uplift of over 80 cm has been observed. The deformation could cause overturning and massive CO_2 degassing if the lake is saturated. There is thus an urgent need to analyse the lake's chemistry and morphology during this unresting phase of the caldera. We present results of a lake survey from August 2024, the chemical characteristics and sublacustrine geological structures. We performed water column profiles using seabird multi-factorial measurements distributed across the lake, which is slightly layered. To test dissolved CO_2 concentration, we sampled spot analysis at different locations and depths. Results show a concentration of dissolved CO2 over 480 mmol/m^3 at the bottom of the lake (220 m). We suggest that it originates from the emanation of CO_2 from sublacustrine vents and fault zones located at the lake bottom, also observed with an underwater drone for the first time in 2024. The collected data suggests that the concentration of CO_2 is far from saturation (<1%), and a catastrophic degassing event is unlikely in the current unrest phase. We further combined the high-resolution DEM from onshore drone flights in 2023 and 2024 with the 2012 and 2014 bathymetric data and obtained the first complete structural map of the Öskjuvatn caldera system. Together with the chemical analysis and underwater footage, it provides an important overview of the lake activity during an unresting phase of a caldera.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Probing the pre-, syn-, and post-caldera: a field, micro-CT, and petrological study of Mt. Ijen volcano, Indonesia

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Caldera-forming eruptions (CFEs) in Indonesia have produced some of the most destructive eruptions in history – the Tambora eruption in 1815 being the most recent VEI-7 eruption in the historical record. The island of Java, home to most Indonesians, hosts several CFEs, including the Ijen Caldera Complex (ICC). Despite its large size (ca. 20 km in diameter) and relatively recent formation (between 300 and 50ka), it remains comparatively poorly understood. Kawah Ijen, ICC's active stratovolcano, hosts the world's largest acidic lake, where fumaroles emit globally significant quantities of sulfur and toxic metals into the surrounding environment. While being mostly quiescent today, the ICC experienced a phreatomagmatic eruption at Kawah Ijen as recently as 1817. North of the caldera, substantial ignimbrite deposits testify to the scale of the system and its eruptive potential. The age, duration, scale, and impact of this CFE are unknown, nor is the temporal evolution of the volcanic system post-CFE. To address these knowledge gaps, we present preliminary results of our 2024 field campaign, alongside our recent micro-computed tomography (micro-CT) measurements of erupted products from Kawah Ijen. We provide some of the first documented textural and geochemical descriptions of the ICC CFE, both in the field and under the microscope. Our micro-CT measurements allow us to provide the first estimates of magma ascent rates for Kawah Ijen's paroxysmal 1817 eruption. Together, these datasets provide a window in to how a complex and potentially dangerous caldera has evolved through time and allow for better assessment of future activity.

Theme: 3. Volcanic processes

Session 3.11: Multidisciplinary perspectives on the dynamics and hazards of Collapse Calderas

Allocated presentation: Poster

Origin and tempo of Miocene large caldera forming silicic eruptions in the Pannonian basin: What we can learn from the zircon and volcanic glass database

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Neogene to Quaternary magmatic activity in the Pannonian Basin (Eastern Central Europe) was preceded with the most voluminous silicic volcanic eruptions in Europe in the last 20 Myr. They resulted cumulatively in more than 4,000 km^3 of tephra deposited during a period of major lithospheric extension. The timing of the largest eruptions has been determined using zircon U-Pb geochronology, indicating several eruptive phases between 18.1 Ma and 14.4 Ma, representative of an ignimbrite flare-up period, followed by further eruptions to the east between 13.1 Ma and 11.5 Ma. Volcanic glass, zircon and bulk rock geochemical data yield specific geochemical fingerprints for each eruption and suggest the development of different silicic magma

types. Thus, these fingerprints can help to correlate eruptive products, even with scattered distal occurrences over large distances and in case of severe alteration. We compare and correlate the proximal and distal volcanoclastic beds occurring in Hungary, Czech Republic, Slovakia, Germany, Austria, Croatia, Italy and Romania. Based on coeval ages and similar zircon and glass trace element compositions, the largest eruptions occurred at 18.1, 17.3, 14.9, 14.4 and 13.1 Ma, eruptions which might possibly reach VEI 7-8 size. Furthermore, the presence of several hundred meters of continuous volcaniclastic deposits of the same age indicates these rocks were sourced from caldera-forming eruptions. Volcanic ash was deposited over 1,000 km away from the eruption centers and occasionally accumulated by local redeposition in subaqueous environment, indicating the scale of Miocene volcanism was far greater than previously thought.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Talk

Plume dynamics and source parameters of the Veiðivötn 1477CE basaltic Plinian eruption retrieved from field work and plume modelling

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The Veiðivötn 1477 CE basaltic explosive eruption occurred along a discontinuous fissure measuring approximately 70 km in length in southern Iceland. An estimated 10 km^3 of basaltic tephra were emitted, covering an inland area of around 53,000 km^2. These tephras reached as far as Greenland and Scandinavia, indicating a powerful eruptive plume that extended high into the atmosphere, dispersing volcanic ash across extensive distances. Despite being one of Iceland's most significant historical eruptions, the Veiðivötn 1477 CE event has received limited attention. Information regarding its volume, isopachs, and petrological data remains sparse. In this study, we present new field data collected between 2023 and 2024, focusing on tephra grain size distribution (TGSD), product density, and deposit mapping. By integrating this field data with a one-dimensional physical plume model (PPM), we can estimate the critical Mass Eruption Rate (MER) prior to column collapse for various volatile contents, as well as the maximum column height. We modelled the plume for a polar atmosphere and under different complex wind profiles. Our model results suggest a MER necessary to generate a plume consistent with the field data, ranging from 10^7 to 10^8 kg/s and a maximum plume height between 15 and 25 km for volatile content of 1-2 wt%. This study provides a fresh perspective on utilizing one-dimensional models to predict critical conditions and refine essential values. Our findings also underscore the significance of gas content in sustaining a stable plume during Plinian basaltic eruptions.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Talk

Turbulence-induced particle clustering: potential for aggregation in volcanic jets

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During volcanic eruptions, most aggregation of ash particles is attributed to gravitational settling. However, we suggest turbulence, specifically preferential concentration or the clustering of particles along eddy margins, is an important additional aggregation mechanism that needs further investigation. To begin our investigation, analog experiments of particle-laden volcanic jets with Reynolds number around 1.2×10^4 are analyzed which display clustering of dense, small particles along small eddies. Feature tracking velocimetry algorithms calculate turbulent kinetic energy dissipation rates, ε, of 1–25 m^2/s^3 near the vent, which result in Kolmogorov Stokes numbers, St_η, of 1–10. With these flow conditions, we suggest that particles cluster around eddy margins and aggregates begin to form in the upward turbulent motion of the jet. When the ambient air contains water, the aggregates are preserved upon deposition. Assuming self-similarity, we apply the scaling from the experiments to the 18 May 1980 eruption of Mount St. Helens, Washington, using a 1D model which calculates an energy dissipation rate, ε, between 1–22 m^2/s^3. This results in vesicular ash particles < 80 μm have a St_η between 0.1 and 10 within the lowest 14.5 km of the plume where aggregation may be initiated inside the turbulent flow. These grain sizes are consistent with descriptions reported in the literature of ash particles < 90 μm forming aggregates. Our experiments show that particle clustering as a mechanism for aggregation warrants further research on collision rates, sticking efficiency, and aggregation rates to improve forecast models for ash transport and deposition during volcanic eruptions.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Talk

A tephra transport and dispersion model considering volcanic ash fingers

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Gravitational instabilities driven by particle settling at the base of volcanic plumes generate highly concentrated currents of volcanic ash, known as “ash fingers” (e.g., Carazzo and Jellinek, 2013). When the falling velocity of ash fingers, v_f, exceeds the terminal settling velocity of individual particles, v_t, ash fingers enhance the ash sedimentation rate. To accurately reproduce and predict ash arrival times and sediment distributions, volcanic ash transport and dispersion models (VATDMs) must account for the finger effects (Takishita et al., 2024). In this study, we incorporated the influence of ash finger formation on particle velocities into a VATDM based on the FALL3D framework (Folch et al., 2020). The finger velocity, v_f, was calculated as the function of the characteristic particle velocity and particle concentration using an empirical formula derived from laboratory experiments (Hoyal et al., 1999). The characteristic particle velocity was determined as the mass-weighted mean v_t across all size bins. Particles were assumed to behave as part of ash fingers and settle at v_f, when v_f exceeds v_t in each size bin (every 0.5 ϕ). We simulated the volcanic ash load distribution over a 15×15 km area for two Vulcanian eruptions with 2.5 and 4.7 km plume heights. Particles smaller than 3 ϕ were more efficiently sedimented by ash fingers compared to scenarios that ignored finger effects. Applying this model to eruptions of Sakurajima volcano, Japan, we discuss the impact of incorporating ash fingers on estimating the spatial distribution and arrival time of volcanic ash deposits.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Talk

Comparing and evaluating two one-dimensional volcanic plume models using the Independent Volcanic Eruption Source Parameter Archive (IVESPA) database.

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Explosive volcanic eruptions generate plumes which can pose direct threat to life and long-term health issues, cause widespread environmental and infrastructure damage, and interrupt the air traffic. Numerical models for volcanic plume rise underpin our understanding of how eruption source parameters and atmospheric conditions govern plume stability and rise height, and these models are key to managing volcanic hazard operationally. However, these models are subject to large uncertainties, in particular associated with the treatment of turbulent entrainment and water phase change processes in the plume. Here we take advantage of the new IVESPA database to evaluate and characterize two one-dimensional (1D) models: the Geneva and Plumerise models. IVESPA gathers all main eruption source parameters, their uncertainties, and atmospheric profiles for 134 well-observed volcanic events. We use it to determine entrainment coefficients minimizing the error on predicted plume height for each model, propagating uncertainties using a Monte Carlo simulations. Moreover, we assess the best approach to account for water phase change in 1D models, in particular for tropical plumes rising in humid atmospheres. Last, we compare the performance of both 1D plume models to the canonical power law linking the mass eruption rate to the plume top height. Our evaluation shed light on potential biases in both 1D plume models and the IVESPA database.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Talk

Eruption column ascent rates obtained using the Advanced Baseline Imager for the La Soufrière eruption in April 2021

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La Soufrière, St Vincent, began erupting explosively in April 2021. The explosive eruption lasted for two weeks and consisted of at least 35 events. The eruption was observed with the Advanced Baseline Imager (ABI) onboard the Geostationary Operational Environmental Satellite (GOES)-East. For a large part of the eruption data was available every minute: providing a unique opportunity to observe the ascent of the eruption columns. The maximum overshooting top heights from three different techniques are presented: (1) estimating the neutral buoyancy height from brightness temperature measurements and working backwards from this to estimate the overshooting top heights; (2) using the position of the coldest pixel relative to the volcano and relating this to the parallax between the satellite instrument and the ash column; (3) incorporating estimates of umbrella and maximum column heights from Horvath et al. (2022; doi:10.5194/acp-22-12311-2022) who estimates the height using side angle measurements from ABI on GOES-West (10 minute resolution). Combining the estimates of the maximum heights with event onset times based on seismic data (Sparks et al., 2024; doi:10.1144/sp539-2022-286) and estimates of the time at which the column reaches its maximum height (timing of the coldest pixel) it is possible to estimate the average ascent rate of the eruption column. This approach has been applied to 18 explosive events during the La Soufrière eruption, the majority of which have an average ascent rate of 20 - 35 m/s.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Talk

Entrainment parameterization for volcanic plumes with pulsating source parameters

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Eruption columns occur in gravitationally stable (buoyant plume) or unstable (collapsing) mass transport regimes. Eruption hazards can be predicted with known eruption source parameters (ESPs) and rates of ingestion of atmosphere (entrainment) where they are relatively constant (steady) over time. However, most eruptions have unsteady ESPs, which change faster than erupted mixture rise time, and have poorly understood entrainment and rise dynamics. We use a multimethod approach to test a source Pulsation number that predicts entrainment into unsteady volcanic plumes with pulsating ESPs. We conduct analog experiments on pulsating buoyant flows of fresh water injected into a density-stratified saltwater layer, and model them using three-dimensional numerical simulations, to test the Pulsation number-entrainment relationship and characterize the turbulent kinetic energy spectrum. Based on the entrainment rate predicted by the Pulsation number, we classify experimental and simulated plumes into the steady plume, connected thermal, and discrete thermal regimes. We use Doppler radar and thermal camera measurements of unsteady ESPs at Sabancaya volcano to show that the Pulsation number can predict the effective entrainment rate of air into unsteady eruption plumes. Measurements of the vertical speed and outer plume temperature variations taken above the eruption plume source reveal a turbulent kinetic energy dissipation rate linked to the formation of large coherent vortices that are efficient at entraining ambient air. We combine our empirical Pulsation number-entrainment relationship with the semi-empirical Richardson number-entrainment formulation of previous studies to provide a way forward towards a generalized entrainment parameterization for use in 1D eruption column models.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Large explosive eruptions are dominated by pyroclastic flows instead of buoyant plumes: insights from a global data compilation

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The dynamics of Earth's largest, most voluminous eruptions (≥100 km^3 ejecta) are poorly understood. Here, we explore the question of whether these very large eruptions can be treated as scaled up versions of moderate volume historical eruptions, or whether they should be treated as fundamentally different Earth system phenomena. To examine this, we compile fall deposit and ignimbrite volume data for 74 explosive eruptions worldwide that are magnitude 4 or greater, and use this dataset to assess how material is partitioned into buoyant plumes versus pyroclastic density currents as a function of eruption magnitude. Importantly, we filter our results by overall distance from seas/oceans, so that we can focus in on the eruptions for which preservation of the deposits is as reliable as possible. After filtering, we find that the largest eruptions are dominated by ignimbrites and not fall deposits, implying that, co-ignimbrite plumes notwithstanding, there may be little or no buoyant plume component to eruptions of the highest known magnitudes. This result is consistent with model simulations showing that the pyroclastic material produced during larger events is emplaced in density currents alone, and highlights important considerations for contemporary eruption simulations, the fate of volcanic gases relative to solid mass, and subsequent appraisals of the climatological and environmental impacts of explosive volcanism on Earth.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

New model for aggregation of ash in explosive volcanic eruptions

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In this work we propose a new three dimensional model for the modelling of ash aggregation in Plinian-phreatomagmatic volcanic eruptions. The model comprises the coupling of the compressible Navier-Stokes equations with the population balance equation in the large eddy simulations framework. Similarly to a previously proposed multiphase model for volcanic eruption columns, an equilibrium-Eulerian approach is used to represent the transport of particles which are assumed to be low inertia and two-way coupled with the flow. For the aggregation process we deploy our recently developed methodology which is tailored to explicitly calculate the size distribution and conserve the mass of particles by identifying the source bins of the particles which compose every newly developed aggregate. We firstly validate our approach against other computational models based on the results presented in a inter-model comparison study and secondly, we display the effect of aggregation in the eruption column and the final size distribution of particles which survive into the far field by using 20 size classes of ash particles. The results set the baseline for obtaining valuable insights regarding the interaction between turbulence and ash aggregation. This is an essential step towards the calibration of real time one-dimensional plume models which are used for the initialisation of dispersion models.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Evaluating the importance of ash aggregation representation: insights from a three-dimensional plume model.

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While many field studies document ash aggregate presence in fallout regions, and the role of aggregation in stripping fine ash from eruption clouds is widely acknowledged, numerical plume models often neglect or oversimplify ash aggregation processes. This inadequate representation leads to considerable uncertainties and errors in the eruption source parameters used to initialise operational ash dispersal models, compromising precision and limiting forecast performance to levels below those required to ensure safe and efficient flight operations during explosive volcanic eruptions. Using the plume model ATHAM to simulate the eruption of Mount Redoubt, Alaska (2009), this study will evaluate the importance of adequately representing ash aggregation in volcanic plume models towards achieving more robust plume evolution and eruption source parameter constraints. The study will explore and test aggregation schemes of varying sophistication to highlight the necessity of developing a theoretical understanding of ash aggregation processes in numerical models with more comprehensive and explicit considerations of plume dynamics and microphysical processes. We will demonstrate the feedbacks between ash aggregation and plume development and quantify the significance of ash aggregation for long range transport.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Characterization of pyroclastic fall deposits from virtual volcanoes using a new tephra simulation code (TWiCE)

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We employed a new tephra simulation code based on an advection-diffusion model named TWiCE to simulate pyroclastic eruptions under simplified topographic and wind conditions, aiming to quantitatively understand the mode of tephra dispersal. Specifically, we focused on the simulation results plotted against the classical D–F diagram by Walker (1973) to evaluate both the validity of the simulation and the D–F diagram itself. In Walker's scheme, the maximum mass loading at the source vent is defined as Smax. The parameters D and F are defined as the area enclosed by an isopach of 0.1Smax (in km^2) and the percentage of the <1 mm fraction along the dispersal axis of 0.01Smax, respectively. Our numerical experiments demonstrated that, within realistic ranges of eruption intensity and initial grain size distribution, the simulation successfully reproduced D and F values consistent with the empirical relationships depicted in Walker's diagram. However, the results revealed that determining Smax, which is challenging to observe in actual eruptions, significantly influences the outcomes. Additionally, we identified a notable dependency on a parameter called "plume thickness", which governs particle segregation as a function of plume length.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Sensitivity of partial column collapse to exit velocity, ambient wind and particle size

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The eruption of Mt Pinatubo in 1991 in its climactic phase formed the strong case of the volcanic plume model intercomparison study (Costa et al. JVGR 2016) and exhibited partial column collapse in the lower part of the plume. This complex behaviour was captured by three-dimensional (3d) large-eddy simulations (LES) such as those performed by the ATHAM model. Using this model we explore the extent to which this behaviour is determined by the exit velocity and the particle size in addition to the mass flux. We conduct sensitivity tests by systematically varying the exit velocity, ambient wind speed or particle size for the strong case and its companion case in the intercomparison study, the weak eruption, which was based on the eruption of Shinmoe-dake in 2011. We consider how entrainment and mixing are affected by partial column collapse both of which are important in determining whether a plume becomes positively buoyant.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Evaluation of eruption source parameters using infrasound and plume modelling

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Volcanic ash injection into the atmosphere during eruptions poses a significant threat to aviation, making accurate forecasting of ash dispersal a priority. These forecasts rely on empirical and numerical models that require accurate estimates of eruption source parameters (ESPs), such as mass eruption rate and maximum column height. In this study, we exploit infrasound data recorded during June 2021 eruptive activity at Mt. Etna, Italy, to assess its potential for near-real-time estimation of eruption rates. We calculate a time series of flow velocity at the vent, accounting for topographic scattering and the effects of vent geometry on acoustic source radiation. During periods of sustained paroxysmal activity, inferred flow velocities range between 50–125 m/s. Validation against independent ground-based remote sensing measurements confirms the reliability of our estimates. Using these infrasound-derived flow velocities as input for a 1D plume model, we also estimate the maximum height of the eruption column. We demonstrate how the infrasound technology is useful for assessing eruption rates for volcanic plume models. By integrating real-time infrasound workflows with operational plume modeling, this approach could significantly enhance decision-making and risk mitigation strategies at active volcanoes.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Investigating the impact of atmospheric conditions, ash aggregation and turbulence on volcanic cloud spreading and particle settling

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Explosive volcanic eruptions release large volumes of tephra into the atmosphere, where it is dispersed by wind and deposited on the ground. The dispersal and sedimentation of tephra are influenced by key processes such as ash aggregation, volcanic cloud turbulence, and shear at the cloud base. Additionally, tephra interacts with atmospheric conditions (e.g., wind, temperature, humidity, and atmospheric turbulence), leading to complex dynamics. To better understand these processes, we employ advanced numerical modelling techniques. Specifically, we implement a 3D model in Palabos (Parallel Lattice Boltzmann Solver) that combines the lattice Boltzmann method (LBM) for fluid dynamics with a low-diffusive finite difference scheme (WENO) to solve advection-diffusion equations. This hybrid approach is further fed by field observations and laboratory experiments, offering a detailed perspective on cloud-atmosphere interactions. We use the 2010 Eyjafjallajökull eruption (Iceland) as case study where different sedimentation processes have been observed. Our preliminary results show that the mixing induced by the turbulence allow particles to reach the ground earlier than in a simpler shear-only scenario. By combining these methodologies, our study intends to enhance the accuracy of models predicting ash dispersion and sedimentation, ultimately improving hazard assessments related to volcanic eruptions.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

The impact of ice particles in satellite thermal infrared fine ash estimates

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Explosive eruptions inject a lot of volcanic particles, of different shapes and sizes, in the atmosphere. From lapilli, mainly responsible for tephra fallout in proximity of volcanoes, to fine ash particles (< 64 μm in diameter), responsible for potential damages to aircrafts due to a longer atmospheric residence time. Satellite thermal infrared (TIR) observations are an essential asset to monitor the dynamic and dispersion of these particles. Sometimes, ice enriched volcanic clouds can hide the presence of fine ash particles, intensifying the risks for the aviation. However, how ice particles affect the satellite retrievals is not investigated yet. In this work, we show how the fine ash total mass (FaTM) load in atmosphere varies depending on the ice fraction assumed in an aggregate. The 15 January 2022 Hunga Tonga-Hunga Ha'apai hydromagmatic eruption is used as case study. We assume three different levels of ice inclusions: 10%, 25% and 50% with a well mixing of these particles in the aggregate. We also consider two types of aggregate shapes: one spherical and less porous; one irregular more porous. We then use a radiative transfer model to simulate the radiance observed by a TIR passive radiometer, in presence of the assumed aggregates. We estimate the FaTM load by comparing the simulated radiances with the radiances observed by the TIR passive radiometer on board the GOES-17 satellite. The results show how FaTM load doubles in presence of spherical aggregates compared to irregular aggregates.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Ash Finger Formation at the Base of Spreading Volcanic Clouds: Insights from Analogue Experiments

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Tephra sedimentation following explosive volcanic eruptions is commonly modelled as governed by the settling of individual particles. However, collective settling processes, such as settling-driven gravitational instabilities (SDGIs), can shorten the atmospheric residence time of volcanic ash particles. These instabilities generate downward-propagating plumes known as fingers that descend faster than the terminal fall velocities of fine ash (< 63 μm). This enhanced sedimentation can affect deposit interpretations and dispersion forecasts. However, despite being commonly observed below eruption plumes and clouds, ash fingers have not yet been included in ash dispersal models. While previous studies mostly focused on finger formation in static, density-stratified fluids, we investigated fingers beneath particle-bearing gravity currents in lock-release experiments to better simulate spreading volcanic plumes. Using a dense ambient fluid and a buoyant gravity current containing 40 μm glass beads (1 g l^{-1} concentration), we employed particle image velocimetry to study interactions between shear and SDGIs. By varying the ambient fluid density, we simulated ash cloud spreading at different speeds. Qualitative results revealed two finger formation mechanisms: classical SDGIs and a vorticity-driven process. Quantitatively, we found that boundary layer shear reduced finger formation but did not alter their sedimentation behaviour. Once formed, the fingers exhibited entrainment and velocity characteristics similar to those in static configurations. These findings suggest that while shear inhibits finger formation, it does not significantly affect their overall role in sedimentation dynamics, highlighting the importance of incorporating ash fingers into volcanic ash dispersion models.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Ash Fingers Without Aggregation: Insights from the July 23, 2024 Paroxysm at Etna Volcano

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Ash fingers are descending particle-laden plumes that develop underneath volcanic clouds and have been observed to form during several volcanic eruptions worldwide. Similar to volcanic ash aggregation, these features drive the rapid collective settling of volcanic ash particles, affecting their sedimentation behaviour in the atmosphere and representing a significant source of uncertainty in forecasting ash dispersion following explosive eruptions. However, obtaining accurate measurements of ash fingers properties remains challenging, as they are visible only under certain eruptive and atmospheric conditions that are not well defined yet. Also, ash fingers are poorly constrained from post-event analysis of deposits, which can be characterised by bimodal grain size distributions in case of ash aggregation. To date, the field quantitative description of ash fingers remains limited, emphasising the importance of improving their characterisation through further field studies. This study focuses on ash fingers formed during a paroxysm event at Etna volcano (Italy) on July 23, 2024, using high-resolution (HR) video footage captured during the eruption. Notably, this event is particularly significant as no ash aggregation was observed, allowing us to isolate the deposit signature of ash fingers without the effects of aggregation. We analysed key finger characteristics, including downward velocity, width and spacing, and complemented these observations with measurements of tephra deposition performed simultaneously directly in the fallout, like sedimentation rates and grainsize distribution. This study offers new insights into the dynamics of ash fingers in the absence of aggregation, advancing our understanding of their part in ash dispersion and sedimentation processes.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Laboratory and field measurements of the electrical charge carried by volcanic ash particles and observations of ash aggregates

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Several mechanisms contribute to electrification during explosive volcanic eruptions, including fracto-emission from fragmentation and tribo-electrification from particle collisions. This electrification explains the occurrence of volcanic lightning and enhances aggregation by increasing electrostatic attraction and sticking efficiencies between ash particles. The resulting larger aggregates settle faster than individual particles, affecting sedimentation rates and particle residence time in the atmosphere. However, direct measurements of electrical charges on volcanic ash particles remain rare, limiting our understanding of how ash electrification influences aggregation. Additionally, laboratory experiments are needed to assess the impact of electrical charges on sticking efficiencies. This study presents a cost-effective, portable device designed to quantify the charge and fall velocity of individual volcanic ash particles and aggregates. Using a charge amplifier circuit and an Arduino microcontroller, the device records the very small voltages induced by charged particles crossing a Through-Type Faraday Cage (TTFC). The device was deployed in two field campaigns at Sakurajima volcano (Japan, November 2023) and Etna volcano (Italy, July 2024). At Sakurajima, charges ranging from 0.5 to 150 pC and settling velocities of 0.1 to 5 m/s were detected, with aggregates observed in deposits despite low explosive activity. In contrast, no charges or aggregates were observed at Etna during high-intensity paroxysmal explosions. Differences in fragmentation, grain size distribution, or atmospheric conditions may explain this discrepancy. The device was also used in preliminary laboratory experiments focusing on the collision and eventual sticking of charged particles, proving its utility in both field and laboratory settings.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Linking volcanic plume dynamics with sedimentation processes using a multi-GPU accelerated Lattice Boltzmann solver.

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Explosive eruptions release significant amounts of volcanic ash (tephra) into the atmosphere, posing serious threats to communities. Tephra can harm human health, damage infrastructure, pollute ecosystems, and disrupt economic and transport systems. While numerical dispersion models have advanced considerably, gaps remain in understanding processes linked to premature tephra sedimentation, such as particle aggregation and gravitational instabilities. Tephra dispersion and sedimentation depend heavily on source conditions at the volcano vent, requiring a detailed understanding of complex eruption dynamics. Explosive eruptions involve compressible flows, potential transonic behaviors, buoyancy effects, multiphase interactions, and intense turbulence during plume ascent. To explore the influence of the plume dynamics on the sedimentation, we developed a numerical model simulating volcanic plume dynamics from initial stages to wind-driven large-scale dispersion. The model leverages the Lattice Boltzmann Method (LBM) for accurately simulating complex flows and integrates low-diffusive finite difference schemes for effective transport modeling of species in the fluid. A notable feature of our approach is its multi-GPU computing capability, enabling efficient, high-performance 3D simulations on large scales. Model validation against experimental data, including turbulent and thermal jets, demonstrates strong stability and accuracy across various configurations. These results enhance our understanding of volcanic plume dynamics and improve parameterization in operational models, aiding better prediction and mitigation of volcanic hazards.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

The Proper Orthogonal Decomposition (POD) applied to thermal infrared and visible low-cost cameras images in different volcanic contexts

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Remote sensing, both satellite and ground based, has in recent years become an increasingly important role in volcanic monitoring, thanks to improved sensors and cost-cutting of this type of instrument. The VIRSO2 ground based system is a low-cost instrument consisting of three cameras, one working in the VISible (VIS) part of the spectrum and the other two in the thermal InfraRed (TIR) spectral range (8-14 µm). In front of one of the two TIR cameras an 8.7 µm narrowband filter is placed. From the measurements collected, the geometry of the plume, the detection and retrieval of volcanic SO2 can be obtained. The Proper Orthogonal Decomposition (POD) is a technique extensively used in analyzing turbulent fields to decompose a generic scalar or vector field in empirical eigenfunctions and their temporal coefficients. The spatial and temporal volcanic plume dynamics is preliminarily investigated applying the proper orthogonal decomposition to the ground based measurement acquired using the VIRSO2 camera. The use of POD generates a reduced orthonormal basis to approximate thermal image fields. In these years the INGV remote sensing group were carried out many field campaigns using the VIRSO2, covering a wide spectrum of volcanic activity: eruptive (Etna, 1 April 2021), strombolian (Stromboli, May 2023) and degassing (Etna, August 2024; Popocatépetl, February 2023; Sabancaya, November 2022). Using this technique we aim to identify and characterize the different dynamical regimes and patterns acting on the emitted volcanic plume.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

MFIXing Volcanic Plumes: from lab puffs to Fuego's fury

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Multiphase flow solvers have proven useful in the past decades to study the dynamics of volcanic jets and plumes. In this work, we present simulations conducted using the open-source code MFIX —Multiphase Flow with Interphase eXchanges—that we modified to incorporate several closure models and expand the initial and boundary conditions specification framework to include natural-scale conditions. We first show results of reproducing small scale single and multiphase experiments investigating the role of periodically changing source conditions on plume rise and spreading height. We also explore the validity of the added multiphase descriptions (i.e. Large Eddy Simulation, thermal energy modifications) in natural scale by reproducing the weak and strong plume cases following the international benchmarking exercise of 2016 and expand by allowing the use of 2D wind fields. We demonstrate the role of wind shear on influencing entrainment and subsequent plume rise using the 2018 Fuego eruption as a test case. Finally, we illustrate the potential to include other microphysics such as phase changes to explore a broader range of volcanic eruptions and atmospheric conditions.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

3D Numerical Modeling of Umbrella Cloud Growth and Regimes

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Large-scale explosive volcanic eruptions produce clouds that expand horizontally in the stratosphere as density gravity currents, forming “umbrella clouds.” The area of an umbrella cloud serves as a key indicator of eruption intensity. In the case of steady intrusions in a windless environment with the constant Brunt-Väisälä frequency, the horizontal expansion of density gravity currents follows a scaling law based on the elapsed time and the volumetric inflow rate. The flow regimes vary depending on the balance of forces, each characterized by distinct power-law exponents for spreading time (Poret et al., 2016). In contrast, umbrella clouds spread in a wind field with the Brunt-Väisälä frequency changing with height. Umbrella cloud growth also depends on the volcanic plume dynamics. We conducted direct numerical simulations to explore umbrella cloud growth using the three-dimensional pseudo-gas model SK-3D (Suzuki et al., 2005). Parameter studies were performed by varying eruption rates, atmospheric structures, and wind velocities. The results revealed distinct flow patterns, such as umbrella clouds from stable plumes and co-ignimbrite ash plumes generated by pyroclastic density currents. Multiple power-law exponents, including 4/3 and 10/9, were identified, reflecting different flow regimes such as buoyancy-inertial and turbulent drag-dominated intrusion regimes. Interestingly, these power laws did not always correspond directly to flow patterns or specific atmospheric conditions. We summarize the relationships between eruption conditions and power-law exponents and discuss the implications for understanding umbrella cloud regimes.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

New insights into the spatiotemporal evolution of the Y5 phase of the Taupō 232 ± 10 CE eruption, New Zealand

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The Plinian Y5 phase of the Taupō 232 ± 10 CE eruption generated a widespread and well-preserved deposit incorporating fall and coeval PDC deposits. Despite extensive study, there remain conflicting views around the deposits regarding eruption and sedimentation processes. To reconstruct the spatiotemporal evolution of the Y5 and address Plinian eruption dynamics and sedimentation, a detailed dataset of the Y5 deposit characteristics is presented. Analyses for grain size distributions, componentry, and juvenile textural characteristics demonstrate that foreign lithic lithologies and their time-relative abundance can be used to inform vent location, conduit evolution and the balance between PDC and fall activity. Vertical variations in the abundance and relative proportions of different juvenile and lithic pyroclasts, juvenile textures and pumice densities, following the initial development of the vent, define three successive stages within a continuous, relatively steady, eruption: 1) conduit excavation; 2) increasing mass eruption rate towards a climax; and 3) a decrease in mass eruption rate and the acceleration of conduit erosion prior to the Y6 ignimbrite. Vertical bedding features previously documented in the Y5 fall deposit can be demonstrated to be laterally discontinuous and pinch out over length scales of 101-103 m. We interpret these features in the Y5 deposit to result from gravitational instabilities in the umbrella cloud, sedimenting as tephra swathes. Using quantitative analysis such as this provides a field-based foundation for the reconstruction of the spatiotemporal evolution of such eruptions, ultimately providing a pathway for the amalgamation of field data and computational eruption models.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Monitoring ash-laden plumes using geodetic remote sensing techniques

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Climate changes affect all regions of Earth's neutral atmosphere, from the equator to the poles, driven primarily by human activities and volcanic eruptions. The rise in severe weather events and hazardous clouds from volcanic activity or industrial explosions poses serious threats to public health and can cause widespread damage. Additionally, both convective and volcanic clouds present significant risks to aviation safety. In this context, the aim of this work — which is part of the *Convective and Volcanic Cloud* (CVC) sub-workgroup of the IAG Commission 4 on "*Positioning and applications*", section "*Atmospheric remote sensing* — is to enhance the detection of hazardous atmospheric structures by analysing disruptions in GNSS radio wave signals received by ground stations or polar low Earth orbit (LEO) polar satellites (radio-occultation). Three benchmark campaigns/sites are considered to enhance risk detection, warnings, and mitigation strategies for extreme CVC events. This presentation focusses on two volcanoes: Etna (eruptions in 2015, 2018 and 2021) and Ruang (eruption in 2024). Results from GNSS techniques on the 3D structure and height of volcanic ash-laden plumes are obtained by integrating data from other remote sensing methods, including sensors on LEO and GEO (geostationary) satellites. Detecting and monitoring extreme clouds involves quantifying atmospheric refractivity and delay propagation of radio signal to identify anomalies relative to reference data. Developing tropospheric parameters from multi-GNSS data is crucial for reconstructing 3D structures through tomography and creating diagnostic tools based on slant delay observations, aiming to characterise the vertical profiles of CVCs.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

The ash load of Strombolian volcanic plumes

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Eruptive source parameters of volcanic plumes control the ascent, dispersion and fallout of ash and their determination is key to assess related hazards. To estimate in particular the plume ash load, a field experiment was carried out at Stromboli volcano during normal strombolian activity. A new transportable mm-wave Doppler radar measured the reflectivity and Doppler velocity of ash emissions ~100 m above the vent at unprecedented space-time resolution (12.5 m; 1 s) while a disdrometer recorded particle sizes and fall velocities of proximal ash fallout (10 s). In situ reflectivities measured by the radar compared to the reflectivity-concentration correlation derived from the disdrometer provide estimates of the plume near-source particle concentrations. We find bulk and maximum concentrations commonly in excess of the aviation threshold for ash hazards by 2 to 3 orders of magnitude and up to 1 $g.m^{-3}$. Ash-filled volumes initially total <50-80 m in thickness, growing up to 60-180 m in late stages, and show a Gaussian distribution of mass on average. Plume detection durations last in majority 25-50 s, up to 250 s, with the emission phase most frequently lasting less than 25 s. Space-time integration of inferred concentrations using measured ash detection duration, plume thickness, and ascent velocities further provides total ash masses released per emission of the order of a few tens of kg, with only a few percent exceeding 200 kg.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Volcanic lightning and plume dynamics during the 2023 eruption of Shishaldin Volcano, Alaska: Insights from a dry, coarse-grained, basaltic eruption

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Shishaldin Volcano, Alaska, USA, produced 13 eruptive events from July to November 2023, with plume heights ranging 3–14 km above sea level. Eight of the plumes reached an altitude ≥9 km, threatening aviation. Communities, airports, and marine vessels reported ashfall. The tephra deposits were basaltic and predominantly coarse-grained, although co-pyroclastic density current plumes also deposited fine-grained ash. This was a dry eruption (minimal magma-water interaction), with several plumes producing low-moderate rates of volcanic lightning up to 2–3 lightning pulses/min. Here, we investigate how changes in mass eruption rate (MER) and atmospheric conditions influenced the plume and lightning characteristics. We use Vaisala's GLD360 lightning dataset, GOES-18 satellite observations, global data assimilation system (GDAS) meteorological data, and the one-dimensional steady-state plume model, Plumeria, to constrain source parameters for each event. Our results indicate that peak MER was ~$2x10^7$ kg/s (event 11), and the 13 eruptive events produced a total volume of 0.05 km^3. Atmospheric analysis shows that wind speed significantly decreased the height of the observed plumes. Volcanic lightning occurred mainly in events with MER >10^6 kg/s, when the plume height reached above the atmospheric freezing level (approximately -20°C). We conclude that a combination of triboelectrification and ice charging dominated in this dry eruption, given the paucity of mixed-phase microphysics (ice + liquid water) in the plume models. During event 10, lightning data revealed that the plume continued for several hours below the cloud deck, where it was not detectable by satellite, highlighting the value of lightning to assist volcano monitoring.

Theme: 3. Volcanic processes

Session 3.12: Dynamics of volcanic eruption plumes: models and observations

Allocated presentation: Poster

Volcanic Evolution and Activity in the Hoggar Mountains: Insights into Cenozoic Processes

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The Hoggar Mountains, located in central Algeria, represent a significant geological and volcanic region characterized by complex processes that have shaped its landscape over millions of years. This abstract explores the volcanic evolution and activity in the Hoggar, particularly focusing on Cenozoic processes which began approximately 35 million years ago and continue to the present. The region is marked by a series of volcanic events that have resulted in diverse geological features, including extensive basaltic lava flows, trachyte domes, and phonolite formations.The initial phase of volcanic activity involved the eruption of thick basaltic flows, creating a plateau that laid the foundation for subsequent volcanic development. This was followed by the formation of numerous small stratovolcanoes and various volcanic structures, including maars and cones, indicating interactions between erupting magmas and local aquifers. Notably, the Atakor volcanic field within the Hoggar showcases about 450 individual vents and significant stratigraphic variations that reflect a rich volcanic history.Geological studies reveal that the Hoggar region sits atop a domal uplift associated with ancient tectonic movements. The interplay between tectonics and volcanism has led to the erosion of older formations, contributing to the current rugged topography. The presence of ancient rocks from the Tuareg shield highlights the region's geological significance as it has been shaped by both volcanic activity and metamorphic processes over billions of years.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Talk [Invited]

TephATA: A Tephrostratigraphic Framework for the Atacama Desert and its Application on Regional Sedimentary Archives

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Developing chronologies of sedimentary archives in arid environments can be challenging due to the lack of applicable dating methods. However, robust chronologies are essential for studying Earth surface processes through time and for evaluating local paleoenvironmental observations in a regional and global context. In the Atacama Desert, volcanic ash layers occur in various types of sedimentary archives and on various timescales due to the persistent volcanic activity within the Andes. Tephrostratigraphy and -chronology using these ash layers can help to overcome dating limitations. A tephrostratigraphic framework, which places individual tephra layers in stratigraphic and chronological order and shows their regional dispersal, however, is currently absent. Within the CRC1211 "Earth-Evolution at the dry limit", the project TephATA aims to develop a regional tephra database to construct the first comprehensive tephrostratigraphic framework for the Atacama Desert and adjacent regions. The TephATA database uses an extended IGSN meta schema and combines all sample related data (morphological, geochemical, stratigraphical and chronological) in just one repository. TephATA is integrated as a web-based part of the CRC1211 database and offers tools to test tephra correlations (similarity coefficient, oxide plotting tool). Particularly widespread tephra layers are used as independent tie-points for the synchronization of the various marine and terrestrial sedimentary records investigated within the CRC1211. The TephATA repository will contribute to the understanding of the volcanic eruptive history of the adjacent volcanic centers and thus offers crucial information for volcanic hazard assessment, such as the frequency of explosive eruptions and the spatial dispersal of their pyroclastic products.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Talk

Morphological, textural and geochemical analysis of volcanic fallout trapped in proximal marine sequences: towards the identification of new submarine eruptions in Mayotte?

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Volcanic eruptions pose significant risks to residents and infrastructures. Investigating past eruptions is hence crucial to assess them and develop effective response plans and monitoring systems. The Mahoran seismic crisis in May 2018 is an example of such event that affected an oceanic island and led to the creation of the REVOSIMA monitoring network offshore to follow Fani Maoré volcanic activity, responsible for this crisis. During MAYOBS15 and MAYOBS19 monitoring cruises, ~300 m of marine sediments were retrieved from the uppermost submarine slope at ~5 km from Petite-Terre. We conducted an in-depth and detailed investigation of tephra and cryptotephra present in one of the core (MAY15-CS02-S02) with the aim of identifying distinct volcanic events and distinguish primary ash layers from reworked deposits, and determine the aerial or submarine source of these events. This was made possible by careful observations and descriptions of each particle, aided by digital imaging. The quality of the correlation and comparisons between volcanic levels using these methods offered a new way of qualifying and quantifying the nature and proportion of particles. Geochemical analyses of major and trace elements confirmed a phonolitic nature and a submarine origin for the tephra and cryptotephra layers, with related sources situated in the Eastern Mayotte Volcanic Chain (EMVC). This meticulous work provides new, crucial information and constraints for refining Mayotte's eruptive history, and evaluate how submarine volcanism might evolve in this region. It also opens up new avenues for the observation and characterization of tephra and cryptotephra in marine environments.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Talk

Constraints on the timing of East Asian explosive volcanism: insights from cryptotephra deposits preserved in marine and lacustrine archives

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Volcanic hazard assessments are in part constrained by understanding the past behaviour of a volcano (e.g., eruptive frequency and magnitude), this is largely reconstructed using tephra deposits preserved close to source. However, these near-vent eruption records are often fragmentary and incomplete owing to burial and erosion processes, thus potentially hampering the accuracy of hazard assessments. Here we capitalise on the potential of long, undisturbed records of ash fall events preserved in East Asian marine and lacustrine sedimentary archives, typically positioned >100 km from volcanic sources, to plug the gaps in near-source eruption records. The extraction and identification of microscopic ash layers (cryptotephra) from sedimentary archives is adopted to provide important constraints on the timing of mid-intensity explosive eruptions which are frequently under-reported at source. Following detailed cryptotephra investigations we present a new eruption record captured by high-resolution sediment cores (WB06 and WB08) from off the Wakasa Bay (Sea of Japan), which span the last 100,000 years. Detailed geochemical fingerprinting is used to assign >30 tephra and cryptotephra deposits to volcanic source, and where possible to known eruptions. Furthermore, these chemical signatures are used to link the WB06 and WB08 tephra layers to those preserved in the precisely dated sediments of Lake Suigetsu (Honshu Island), providing important chronological constraints on this newly developed eruption record. Our investigations provide evidence of near-vent under-reporting (or grouping) of explosive eruptions and new insights into the repose periods between pre-historic eruptions at individual volcanoes.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Talk

Reconstructing the eruptive activity of Mount Melbourne in northern Victoria Land (Antarctica), characterization of englacial tephra deposits from the southwest flank

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We present a comprehensive characterization of tephra deposits discovered within an ice sequence on the southwest flank of Mount Melbourne, located in northern Victoria Land, Antarctica. This study focuses on the detailed analysis of three distinct fallout tephra layers DPT 1, DPT 2 and DPT 3, including textures, components, major and trace elements single glass composition. DPT 1 represents the lowermost layer and is composed of pumiceous lapilli and ash, it is moderately to highly vesicular with a predominantly aphyric groundmass and rare euhedral to subhedral crystals. DPT 2 is the intermediate layer and consists of dense, poorly vesicular glass shards embedded in a glass matrix ranging from microlite-poor to nearly crystallized. DPT 3 is the uppermost layer, it looks dense to poorly vesicular scoriaceous fragments, rich in microlites and nearly fully crystallized. These deposits are predominantly trachytic, with occasional transitions to trachyandesitic compositions. Major and trace element compositions strongly suggest that they originate from the explosive activity of Mount Melbourne. Notably, no direct correlation was found with previously studied tephra attributed to this volcano, indicating that they represent deposits from three yet undiscovered eruptions, one of which is particularly significant in terms of energy. Therefore, the integration of DPT 1-2-3 within the regional tephra framework from previously studied marine sediments and ice core tephra enhances our understanding of the explosive activity of Mount Melbourne. These insights are also crucial for evaluating volcanic hazards, particularly given the proximity of Mount Melbourne to polar air traffic routes and scientific research stations.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Talk

High-resolution stratigraphy and 40Ar/39Ar geochronology of the Ileret Tuff Complex, Omo-Turkana Basin

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The Omo-Turkana Basin, spanning northern Kenya and southern Ethiopia, is a region of significant paleoanthropological importance. The Okote Member (1.6–1.4 Ma) is notable for its fossiliferous sediments, including well-preserved hominid fossils, interbedded with volcanic ash (tuff) layers. These tuff layers serve as temporal markers in a dynamic sedimentary environment; precise dating of these layers has been crucial for constructing a detailed stratigraphy of the Okote Member. The Ileret Tuff Complex offers a unique opportunity for developing high-resolution stratigraphy for key archaeological sites (e.g. FxJj14E, which contains fossil footprints from multiple hominid species) in the Ileret region. Previous $^{40}Ar/^{39}Ar$ dating analyses of these tuffs lacked the resolution required to differentiate the ages of closely spaced eruptions. The age uncertainties are further compounded by reworking of sequences by post-eruption fluvial processes. This study presents a high-resolution tephrostratigraphic model for the Ileret Tuff Complex by employing a combined approach of field observations, geochemical fingerprinting and high precision (< 0.1%) $^{40}Ar/^{39}Ar$ geochronology. Statistical approaches to geochemical fingerprinting, such as principal component analysis (PCA), allow for identification and correlation of volcanic tuffs and their associated pumice clasts. Utilising a Bayesian approach, preliminary $^{40}Ar/^{39}Ar$ age estimations suggest eruptions at 1.5262 ± 0.0018 (2σ) Ma for the base (Lower Ileret Tuff) and 1.5156 ± 0.0009 (2σ) Ma (Lower Koobi Fora Tuff) for the top of the of the Ileret Tuff Complex. These revised ages and geochemical signatures have important implications for the ages of key hominid fossil sites and our understanding of volcanic behaviour in the region.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Talk

Erupt-spread-emplace-modify: Fate and weight of the Carpathian-Pannonian Region silicic volcanism during Early and Middle Miocene

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Explosive silicic volcanism of the Carpathian-Pannonian Region (CPR) is increasingly recognized as the primary source of tephra across the Alpine-Mediterranean region (AMR) during Early and Middle Miocene. This calls for a unified tephrostratigraphic framework for this period of volcanic activity to resolve the nature, extent, scale and frequency of large silicic eruptions of the CPR, as well as conditions of magma genesis, the timing of changing depositional environments, and climate-related weathering regimes. Here, we present new volcanological, sedimentological, petrological, high-precision and *in situ* zircon geochronological, and zircon and volcanic glass compositional data from distal Lower and Middle Miocene volcaniclastic (e.g., ignimbrites and ashfalls) and residual (e.g., karst bauxites) deposits from southwestern CPR and the Dinarides. We integrate new and existing datasets to provide new constraints on the volcanic history and petrogenesis of the CPR, which occurred between ~18.1 Ma and ~16.8 Ma. Recognition of at least seven

regionally extensive Early Miocene volcanic events suggests that large volume CPR ignimbrite-forming eruptions were more frequent, widespread and larger than previously considered. The multi-proxy approach applied on a distal record of the ~14.32 Ma silicic eruption of the CPR, stored within the Dinaride Lake System, implies more frequent CPR explosive volcanism during the Middle Miocene and permits us to interpret the emplacement of over-thickened volcaniclastic deposits as volcaniclastic turbidites. Finally, we unravel the Dinaridic residual record of the long-lasting Oligo–Miocene volcanic history of the AMR as well as the timing of intense chemical weathering at mid-latitudes during this time period.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Records of Katla's explosive past preserved in archaeological contexts and fossil beaches in Norway

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Ocean-rafted pumice from Iceland is found in archaeological sites and on modern and paleo-beaches across the North Atlantic. While not as accurate as tephrochronology, ocean-rafting events can be fingerprinted to their volcanic source and contribute to dating coastal sedimentary records and landforms, including archaeological sites. They also provide records of large explosive eruptions that might not be preserved near the volcano and as such can be used for petrological and geochemical investigations. We focused on beach and archaeological pumices from Norway to better understand the nature and frequency of Holocene silicic eruptions from Katla, while also improving age control for shoreline displacement reconstructions and archaeological contexts. Pumice was found on several levels of raised shorelines along the Varanger and Trøndelag coast, reflecting deposition and subsequent preservation at certain times and in specific settings. Glass compositions of pumice samples form a continuous array that mostly overlaps with the <7.2 ka SILK-tephras from Katla, with one sample plotting outside the Katla field and resembling compositions known for Jan Mayen. Despite some finds in Mesolithic contexts, older eruptives were not found on Early Holocene beach ridges. Pumice availability also varied with climate, being readily accessible in cold bare landscapes but getting covered by peat and vegetation in milder conditions. This is supported by our archaeological data, which suggests access to individual pumice batches becoming limited within hundreds to 2-3,000 years following eruption, rafting and onshore deposition. Our study shows that ocean-rafted pumice provides valuable archives and opportunities for volcanological, geological and archaeological investigations.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Marine tephrostratigraphy in the Sunda Strait (Indonesia)

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Krakatau volcano in the Sunda strait is famously infamous for its 1883 eruption, which represents one of the largest explosive and climate-changing eruptions in historic times (Sigurdsson et al., 1991). However, very little is known about the pre-1883 explosive eruptive history of Krakatau. Drill core data suggests an eruption in the Sunda Strait at ca. 60 ka BP, but it remains uncertain if this eruption originated from Krakatau volcano (Ninkovich, 1979). We therefore reinvestigated 9 marine gravity cores from two RV SONNE cruises. Expedition SO139 recovered two cores ~120 km SE of Sumatra in the Sunda fore-arc basin (cores SO139-74 KL and SO139-50KL), and the recent SO299/2 expedition recovered sediment cores in the vicinity of the Krakatau caldera (SO299/2-GC2 to GC9). The sediments in the distal coring sites (SO139) go back to ~300 and 560 ka, and contain multiple tephra layers orginating from explosive eruptions of the Sunda arc area. The sediments recovered in the proximal cores (SO299/2) are probably limited to historical times. We applied geochemical finger-printing on volcanic glass shards using major and trace element compositions to unravel the provenance of the various marine tephra layers. The glass shard compositions from tephra layers in SO139 cores range from basaltic-trachy-andesite to rhyolite, indicating different volcanic sources with varying eruption frequencies over time, whereas the tephra layers in SO299/2 cores contain glass shard compositions from andesite to rhyolite, mainly featuring compositions known from the 1883 Krakatau eruption, as well as historical Anak Krakatau eruptions.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Upper Miocene volcanic ash layers from central Italy: tracking down the volcanic source

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Since the Eocene, the Mediterranean region has experienced intense explosive volcanism. These eruptions ejected tephra, including fine-grained ash, which was dispersed widely through the air before settling as ash layers. Many of these layers are preserved in continental and marine sedimentary basins, offering crucial insights into historical volcanic activity. However, identifying the sources of numerous ash layers remains a significant challenge. In central Italy, the presence of numerous ash layers is well-documented in the literature, but their specific volcanic origins are often uncertain. In this study, we analyze upper Tortonian (~7.6 Ma) ash layers sampled from three distinct localities spanning from the Tyrrhenian to the Adriatic coasts of Italy. Our findings are compared with previously described data in the literature. Using electron microprobe geochemical analyses of biotite crystals, U-Pb ID-TIMS and LA-ICP-MS geochronological dating, and trace elements/Lu-Hf isotope analyses on zircons, we enhance our understanding of these ancient ash deposits. Several volcanic centers were active during the late Tortonian, including the Massif Central (France), the Valencia Trough (Spain), the Betics-Rif orogen (Spain-Morocco), the eastern Carpathians (Romania), and Capraia Island (Italy). Through precise radioisotopic dating and geochemical comparison, we identify the Upper Miocene Capraia Island volcano (Tuscan Archipelago) in the northern Tyrrhenian basin as the most likely source of these ash layers.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

High-resolution Reconstruction of the 10,000-year history of Asama-Maekake volcano, central Japan

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Asama-Maekake Volcano, one of Japan's most active volcanoes, has been the focus of an ongoing, national research project "Integrated Program for Next Generation Volcano Research and Human Resources Development". This study addressed challenges in stratigraphic reconstruction caused by varying deposit distributions, burial of older layers, and lack of unique lithological features for correlation of deposits of different localities. Excavating 33 trenches of 5 meters deep near the volcanic edifice, describing deposits, creating isopach maps, and conducting over 100 radiocarbon datings were made. Combination of extensive trench excavation surveys and many datings was shown to be effective in reconstructing eruption history with high resolution (Yasui et al., 2021). Buried older deposits were excavated and soil beneath them were dated. Eruptions predating 3,000 years ago were frequent but smaller in scale. The average eruption rate was 0.00006 km^3/year from 9,000 to 6,000 years ago, and 0.0001 km^3/year from 6,000 to 3,000 years ago. Since 2,000 years ago, the average eruption rate has been high at 0.0011 km^3/year. Since 2,000 years ago, infrequent but large-scale sub-Plinian eruptions have occurred, with large amounts of pyroclastic material deposited near the crater (e.g. Yasui and Koyaguchi, 2004), and the volcanic edifice is thought to have grown rapidly. In addition, the shape of the step diagram has been volume predictable since 2,000 years ago. If an eruption similar to that in the 18th century were to occur in 2025, the eruption volume is predicted to be approximately 0.21 km^3 (Takahashi et al., 2022).

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Using the tephra record to refine the dating of a West Antarctic ice core

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Ice cores provide globally significant paleoenvironmental records which have numerous applications. Of particular interest are their highly resolved archive of short-term environmental events. The construction of reliable and accurate chronologies is often complicated by ice-flow and compression which can result in large uncertainties in the timing of events. Volcanic signals are an established method of creating tie-points between ice cores, enabling chronological control from robustly dated cores to be transferred to less well constrained records. Volcanic events can be deduced from spikes in the sulphur record but lag times between an event and deposition in the ice and long-lasting signals can result in less accurate tie-points. To combat this, tephra deposits can be investigated to provide age-equivalent and independently dated linkages between cores. Here we present the preliminary results of a tephrochronological investigation of the Fletcher Ice Core (FIC) drilled from West Antarctica by the British Antarctic Survey. Initial analysis suggests the 654 m-long core extends back to 130 ka, with confident dating of the last 3500 years through cross-dating the chemical record with the WAIS Divide core. Guided by previous tephra research in Antarctica, we target specific volcanic events known to have deposited tephra in Antarctica with the aims of i) corroborating the age model of the Late Holocene section of the FIC core and, ii) establishing fixed tie-points for the Late Glacial ice. We outline our results and discuss the significance of our findings for the Antarctic tephrochronological record and applications thereof.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Divided by Geochemistry, United by Geochronology: Tephrochronological Challenges in Turkana Basin, Kenya

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The Turkana Basin, NW Kenya, is a renowned paleoanthropological site preserving fossiliferous sequences intercalated with volcanic ash (tuff) layers that provide critical age constraints for hominin species and their cultural technologies. Establishing a tephrostratigraphic framework within the basin relies heavily on $^{40}Ar/^{39}Ar$ geochronology derived from feldspars found in entrained pumice clasts and relating pumice glass chemistry to its host tuff. However, heterogeneous geochemical signatures found within volcanic products from a single eruption can complicate temporal correlation of tuffs. Here, we investigate two key tuff horizons — the Morutot and the Orange tuffs — spanning a critical period of lithic technological advancement in the Turkana Basin (e.g., from developed Oldowan to early Acheulean). Utilizing shard-specific major and LA-ICP-MS geochemistry, we identify at least two and four distinct glass geochemical signatures for Morutot and Orange tuffs, respectively. Despite these geochemical heterogeneities, we are able to reconcile the diverse geochemical products by obtaining high precision $^{40}Ar/^{39}Ar$ ages utlising new-generation multi-collector mass spectrometers (e.g., ARGUS VI+) and tie them to distinct eruption events. High-precision $^{40}Ar/^{39}Ar$ ages yield distinct eruption ages for the Morutot Tuff at 1,618.5 ± 0.6 ka (±1.2 ka, 2σ, including external uncertainties) and Orange Tuff at 1,758.5 ± 0.4 ka (± 0.8 ka). This integrated approach not only refines the tephrostratigraphic framework of the region, but also provides insights into silicic magma dynamics, highlighting the potential of combining geochronology with detailed geochemical analysis to address existing challenges in tephrostratigraphy.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Santorini's eruptive past from new deep-drilled marine tephra records. IODP Expedition 398 Hellenic Arc Volcanic Field.

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Santorini Volcano belongs to the Christiana-Santorini-Kolumbo Volcanic Field (CSKVF), the southernmost volcanic field of the South Aegean Volcanic Arc. Known for its highly explosive volcanism and caldera-forming eruptions, Santorini's terrestrial volcanic deposits have been extensively studied, revealing activity from c. 650 ka to present. While terrestrial records show that Santorini's volcanism evolved from predominantly phreatomagmatic and effusive eruptions (650-360 ka) to more explosive activity including several Plinian and caldera forming events (360 – 3.6 ka), only the last 200 kyr of volcanic activity are well constrained. The early history of the volcanic field, however, lacks a continuous eruption record. Here, we present the revised tephrochronostratigraphy of Santorini Volcano using marine sediments from eight drill sites within the CSKVF drilled during IODP Expedition 398. Geochemical fingerprinting of the tephras enabled the identification of most of the known Plinian eruptions of young Santorini, as well as numerous "new" volcanic events related to interplinian phases. Furthermore, our results show that explosive volcanism occurred long before 360 ka. These findings highlight the importance of complementary (marine-terrestrial) studies to reveal the most complete eruption history of volcanic systems.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Integrated proximal-distal Tephrochronology of Towada Caldera, northern Honshu (Japan)

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Integrating proximal volcanic records with distal tephra (marine-lacustrine-ice) archives is essential to: reliably reconstructing the past eruptive activity of a volcano, tackling potential near-source eruption under-reporting, and offering opportunities to robustly constrain the timing and scale of past eruptions. Towada volcano, located in northeast Japan, became active ~220 ka and has undergone a minimum of 20 eruptive episodes. Towada provides an opportunity to showcase an integrated proximal-distal tephra record, with the volcano providing a key node in the Tephrochronological framework of East Asia and beyond. Large-magnitude events at Towada caldera are known to produce widely traced tephra deposits as both visible and cryptotephra (non-visible) layers, thus providing the potential to better constrain its eruptive history and tephra dispersals. Here, we present new volcanic glass geochemical data (EMP and LA-ICP-MS) from proximal sequences, alongside tephra deposits preserved in lacustrine, marine, and ice core records to further refine the ash fall distributions associated with large-scale eruptions at Towada. Alongside this, we report improved ages for the last two caldera forming eruptions To-H and Towada Ofudo (To-Of), with a precise wiggle-match ^{14}C date for To-H allowing a re-assessment of the regional ^{14}C marine reservoir correction factor for the NW Pacific during the late glacial. These new data allow us to present an updated chronology of the Towada caldera eruptive event stratigraphy, highlighting the requirement of detailed geochemical fingerprinting when correlating tephra units, whilst also emphasising the importance of distal sedimentary records in evaluating eruptive histories in Japan.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Tephrostratigraphy and geochemical correlation of Mount Erciyes parasitic tephra rings with distal Mediterranean S1 Ash Records

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Mount Erciyes, the largest and one of the most active volcanoes in the Central Anatolian Volcanic Province, has produced several Quaternary eruptions, including three Holocene rhyolitic tephra rings: Karagüllü, Perikartin, and Dikkartin. These explosive eruptions occurred along regional faults and were partially destroyed by subsequent lava domes, which erupted at the end of the phreatomagmatic phases, generating block-and-ash flows. Previous attempts to constrain their chronology using cosmogenic (Sarikaya et al., 2019) and radiogenic dating (U/Th-He in zircons; Friedrichs et al., 2021) have lacked precision to determine the eruptive sequence. Therefore, we conducted a detailed tephrostratigraphic study to establish stratigraphic relationships, radiocarbon dating, and glass composition datasets (major and trace elements) for tephrochronological correlation with distal records (e.g., Mediterranean S1 tephra). Our results suggest that Karagüllü erupted first at 11,258 ± 56 cal BP, followed by Perikartin at 9700 ± 100 cal BP and Dikkartin at 9.0 ± 0.6 ka. However, no clear stratigraphic relationships between Dikkartin and the other tephra deposits were identified, and radiocarbon analyses yielded inconclusive results. Trace element analysis confirms distal Karagüllü ashes reached the Black Sea (Cullen et al., 2014). Meanwhile, Perikartin and Dikkartin, geochemically indistinguishable, are correlated with Mediterranean S1 tephra (~9 ka BP; Hamann et al., 2010). Given that Dikkartin is classified as a Plinian eruption (Ersoy et al., 2019) and its age aligns with the S1 tephra, we propose that Dikkartin corresponds to S1. However, simultaneous eruptions of Dikkartin and Perikartin remain possible. Grant PID2023-147255NB-I00 funded by MICIU/AEI/ 10.13039/501100011033.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Bayesian age modeling of a MIS 9 to 8 tephra sequence on the Kamchatka Peninsula (NW Pacific)

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Tephra layers provide a unique tool for correlating paleoenvironmental archives. One of the challenges, however, is obtaining robust age control for each tephra, which is often hampered by a lack of datable material. Here we discuss the dating of a tephra sequence buried in the “blue clays” lacustrine package – the oldest outcropping sedimentary unit in the Central Kamchatka Depression (CKD), whose age estimates vary widely from early to late Pleistocene. Geochemical fingerprinting of the “blue clays” tephra layers using electron microprobe and LA-ICP-MS allowed tephra correlations among several CKD outcrops and the compilation of a composite tephra framework recording twenty-seven explosive eruptions. Seven of these tephras were correlated with their counterparts in marine sediment cores off Kamchatka, and thus their oxygen-isotope and paleomagnetic chronologies provided tie-points for the “blue clays” age model. The obtained sequence offers an ideal opportunity for the Bayesian modelling approach, as it has no directly dated tephra layers but combines in a single stratigraphy a number of tephras dated elsewhere. Our “blue clays” tephrochronological model spans 335-250 ka, or marine isotope stages 9 and 8, i.e. Penultimate Interglacial and the following cooling. Correlations of tephra layers revealed that independent source chronologies strongly support each other, yielding a uncertainty ≤10 ka. Correlations of precisely dated tephra layers provide direct links between marine and terrestrial paleoenvironmental archives from the Okhotsk Sea to Kamchatka and, farther east, across the NW Pacific. The research was supported by the Russian Science Foundation grant #22-17-00074.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Correlating Black Sea (crypto-)tephras to reconstruct the recent explosive volcanic history of Central Anatolian volcanoes

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[7] Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Roma1, 00143 Rome, Italy Glass chemical microanalyses done on 22 (crypto-)tephra layers sampled along a Black Sea sediment core by Cullen et al. (2014) indicate that most of these volcanic ash deposits were sourced by the Central Anatolian Volcanic Province (CAVP). New trace elements microanalyses confirmed the presence of Karagüllü tephra from Erciyes (~11.2 cal ka BP; Sunyé-Puchol et al., 2024), and Güneydag and Korudag tephras from Acigöl caldera eruptions (~21 and 27 ka respectively; Schmitt et al., 2011). Compositionally, it looks like one or two tephras came from Hasandağ volcano (e.g., produced from some of the younger than 60 ka Block-and-ash flow eruptions; Friedrichs et al., 2020), meanwhile all the other crypto-tephras seem to be sourced by Erciyes volcano (up to 11 more, and all older than Karagüllü). These preliminary tephrochronologic correlations would considerably extend the current known volcanic record of Erciyes (i.e., the Holocene Karagüllü, Perikartin, and Dikkartin eruptions, and the upper Pleistocene eruptions of Hacilar ignimbrite and KDR fallout; Friedrichs et al., 2020). This study has been funded by the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie Actions (PÜSKÜRÜM project, grant #101024337), with additional funding from the Add-Sapiexcellence initiative of Sapienza University of Rome (BLACORTEPHRA project, grant #1715/2024) and the Spanish Ministry of Science and Innovation under TURVO project PID2023-147255NB-I00, supported by MCIU, AEI (10.13039/501100011033).

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Volcanic Ash Dispersion across the Antarctic Plateau: Integrating paleo geochemical studies with ash dispersion modeling

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Tephra studies in high latitude (i.e., Antarctica and Greenland) ice cores are key for understanding past volcanic events and climate. Mt. Melbourne, a stratovolcano in northern Victoria Land, East Antarctica, holds an untapped record of volcanic activity that remains poorly understood due to limited chronostratigraphy and insufficiently detailed data. By analyzing tephra and cryptotephra deposits from a 95-meter ice core extracted at Styx Glacier, as well as shallow ice cores near the volcano, this research seeks to reconstruct the eruptive history of Mt. Melbourne through structural and geochemical characterization of volcanic ash particles. The findings will be integrated with atmospheric ash dispersion modeling to produce probabilistic hazard maps, offering insights into the potential reach and impacts of future ashfall events across the Antarctic Plateau. This multidisciplinary approach not only sheds light on the volcano's eruptive history and climate conditions of the past, but also sets the foundation for a more comprehensive understanding of Antarctic volcanic hazards, combining paleoenvironmental data with modern modeling techniques. The results are expected to have implications for volcanic risk management and interdisciplinary geohazards studies.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Refining the marine tephrostratigraphy of the central Mediterranean (40-90 ka): New insights into Late-Pleistocene Campanian explosive volcanism

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Volcanic ash (tephra) preserved in marine sediment cores provide important insights into the eruptive history of a volcano. These distal archives often provide a continuous ash-fall sequence which helps to fill gaps in near-vent records, often caused by burial or erosional processes from subsequent explosive activity. Furthermore, near-source reconstructions on volcanic islands are particularly challenging as much of the erupted material enters the sea. Ischia island (Southern Italy) has produced several large explosive eruptions, including the caldera-forming Monte Epomeo Green Tuff (MEGT) at ca. 56 ka, one of the largest events of the Late Quaternary in the central Mediterranean. However, uncertainties persist regarding the longer-term history of Ischia, due to the limited exposure of key eruptive deposits on the island. This study examines tephra deposits preserved in the marine cores DED87-07 and DED87-08 (Tyrrhenian Sea), alongside newly collected proximal sampled units from Ischia, to better constrain the timing, scale, and ash dispersal patterns leading up to and following the MEGT eruption. Geochemical fingerprinting (EMP and LA-ICP-MS) of distal tephra (glass) is integrated with the near-source record and combined with a new high-resolution oxygen isotope analysis (DED87-07) to construct a more robust tephrochronological framework for activity on Ischia. Additionally, new $^{40}Ar/^{39}Ar$ dating of key eruptive events on the island provides further temporal constraints on this fully integrated eruption record. These new insights into the frequency, dispersal and magnitude of past explosive eruptions on Ischia will aid future hazard assessments.

Theme: 3. Volcanic processes

Session 3.13: Applications, advances and challenges in tephrostratigraphy

Allocated presentation: Poster

Extending La Reunion Island volcanic record to the Mid-Pleistocene: Insights from deep-sea sediments and tephrostratigraphic analysis

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La Reunion Island (western Indian Ocean) is an intraplate volcanic system composed of two shield volcanoes: the extinct Piton des Neiges and the still-active Piton de la Fournaise. During the expedition ERODER4 (2011; doi:10.17600/11200040), approximately 130 meters of marine sediments were recovered to investigate five large volcaniclastic turbidite systems. A 16.74 m-long core (MD11-3347) stood out, as it aimed to reconstruct the past volcanic activity of La Reunion and was hence retrieved on a higher plateau (2890 mbsl) on Piton des Neiges northern flank. Oxygen isotope measurements of planktonic foraminifera (*Globigerinoides Ruber*) indicate an age of 433 ka at the core base, representing the oldest sedimentary archive available offshore La Reunion. A comprehensive sedimentological and volcanological study was performed. Magnetic susceptibility data suggests that 39 horizons could have been derived from explosive eruptions. We further investigated these horizons by acquiring extensive major and trace element analyses on glass shards and pumiceous fragments. Altogether, our study aims at identifying distal deposits from previously known and unknown large (paleo-)volcanic events; assigning these deposits to on-land volcanic centers using geochemical fingerprinting; investigating temporal and geochemical changes of these events; to finally establish a compositional and temporal tephrostratigraphic framework for the region around La Reunion. Here, we report on the first results of this tephrochronostratigraphic study, primarily based on major element chemistry, which identify mugearitic to trachytic volcanic events in the oldest part of the MD11-3347 core.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Talk [Invited]

Gas-driven sudden explosive eruptions: characteristics, precursors, and forecasting

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Explosive eruptions of VEI 3 or less commonly occur with few or no warning signs. Such eruptions can be magmatic, phreatomagmatic, or phreatic in nature, and they are driven by catastrophic release of pressurized gas. Our challenge is how to better forecast these eruptions, and better understand them, with existing and new tools. Here we examine a number of such eruptions, some lethal to humans, which have occurred during the last decade. We describe the key precursory signals that preceded these events, assess whether they developed in a bottom-up or top-down fashion, and compare the different timescales of precursory activity. Based on these events, we identify a number of precursory signals that may be generally applicable and exportable to such systems, and we discuss effective means of using thresholds of these precursory signals and eruptive transitions to improve our forecasting abilities. We outline three grand challenges for the next decade: (1) a full view of subsurface volcano plumbing, (2) complete forecasts of explosive eruptions including when, where, how big, and what type, and (3) monitoring networks that are comprehensive, similar, and systematic in nature.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Talk [Invited]

A decade of multi-parametric monitoring at Poás volcano, Costa Rica: Phreatic eruptions and Hydrothermal-magmatic interactions

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Poás volcano is one of the most active hydrothermal-magmatic systems in the world and is visited by >100,000 tourists annually. The volcano hosts an ephemeral crater lake and is prone to frequent phreatic/phreatomagmatic eruptions (>350 since 2014) with eruptive columns ranging from <50m to 4km. Geochemical and geophysical monitoring techniques used at Poás have evolved dramatically over the last decade, yielding new insights into hydrothermal-magmatic interactions and characterization of potential precursors to eruptions. Phreatic explosions are driven by magmatic degassing through a dynamic semi-permeable vent system with circulating hydrothermal fluids. Increasing gas input from shallow magma is often associated with short-term (days to weeks) precursory signals (seismicity, deformation, SO_2 fluxes, gas compositions and lake changes) to eruptions. Hydrothermal sealing is thought to be an important process in priming the system for more explosive eruptions, and this process occurs slowly (months to years) and can be difficult to distinguish from quiescence. The presence or absence of the lake modifies monitoring signals and plays an important role in eruptive style, which has a direct influence on the impact of eruptive activity. Though precursors to eruptive periods are often clear in hindsight, the timing and nature of these signals varies significantly due to the complexity and dynamism of the hydrothermal-magmatic system, challenging attempts to accurately forecast eruptions. Here we will compare eruptive episodes to highlight key signals that could be useful in differentiating runup to violent eruptions from runup to mild eruptive activity at Poás and other hydrothermal-magmatic volcanoes.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Talk

Degassing Mechanisms: Rincón de la Vieja volcano, Costa Rica

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Rincón de la Vieja is currently Costa Rica's most active volcano, with hundreds of explosive eruptions annually. The high frequency of eruptions is a unique opportunity to study their trigger mechanisms. We present the first semi-continuous SO_2 degassing time series for Rincón de la Vieja from 2022 to 2024 using two new scanning DOAS stations. The dataset shows a significant increase in SO_2 flux over the study period, reaching a peak in late 2023 when the volcano alert level was raised from yellow to orange. During the study period, 567 eruptions were detected seismically and by infrasound and were associated with short-lived peaks in the SO_2 flux. By combining SO_2 flux measurements with seismic data, we distinguished and quantified explosive degassing from passive emissions. Over the 2-year period, a cumulative ~15 ktons of SO_2 were emitted during explosive eruptions, accounting for only ~9.4% of the total SO_2 emissions (~160 ktons). The explosive/total ratio increased from 2022 to 2023. At the end of 2023, this ratio decreased while the passive SO_2 emissions reached its highest. This change in the degassing behavior suggests an opening of conduits in late 2023. Our results demonstrate that explosive eruptions at this volcano are driven by magmatic degassing and increase in frequency in response to magma intrusion and displacement of the hydrothermal system. We estimate that 0.015 km^3 of magma was intruded in 2022-2024. This study highlights the importance of continuous ground-based monitoring to capture the complex dynamics of persistently active volcanoes.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Talk

Hydrothermal mineralisation prior to gas-driven eruptions: mineral seal formation constrained using flow-through experiments

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Gas-driven volcanic eruptions (phreatic eruptions) occur regularly, most often associated with andesite volcanoes with active hydrothermal systems, and are difficult to forecast. Forecasting their eruption onset is one of the key challenges in volcanology, with some exciting progress in automated analysis of unrest signals, coupled with greater understanding of subsurface processes. Hydrothermal minerals are known to form a blockage beneath a vent area, yet the kinetics, tensile strength, and efficiency of that blockage is unconstrained. Here we use a large temperature gradient (~25 to 200 °C) flow-through reactor filled with andesite granules and percolate crater lake fluid through the particles to simulate downwelling fluids being swept into fumarolic conduits. Our results show that within weeks, a mineral seal had formed, restricting fluid flow and significant pressurisation to failure. Hydrothermal minerals present in our experiments are dominantly alunite and anhydrite, with minor sulfur, and rare monazite. This mineral assemblage formed at ~150-180 °C and matches with hydrothermal phases present in ejecta from past gas-driven eruptions. Analysis of the reacted effluent fluid show clear trends during hydrothermal seal formation that we will analyse further to constrain reaction rates of the rock and fluid in the experiments. We expect to re-define geochemical changes occurring in the crater lake, along with the full suite of monitoring data to fundamentally improve gas-driven eruption forecasting.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

Giant phreatic eruptions at Milos Island (Greece)

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Phreatic eruptions rank amongst the most dangerous and enigmatic volcanic phenomena on Earth. These events are typically associated with the rapid vaporization of hydrothermal waters within geothermal systems due to hot fluids and heat from, among others, magma intrusions, suddenly converting thermal energy into mechanical work. Hydrothermal system host-rock fragmentation and the subsequent ejection of particles allow for the accumulation of deposits with no fresh juvenile material involved. Milos Island (Greece), located in the central part of the Hellenic Volcanic Arc, hosts extensive geothermal systems in its southeastern part, where favourable conditions for phreatic explosions occur. The island underwent several phases of phreatic activity during the Pleistocene. Our preliminary results have revealed that at least two exceptional gigantic phreatic eruptions of unknown age (100ka<>1Ma) occurred within the Mesozoic/Palaeogene metamorphic basement. This activity emplaced several eruptive units up to 50 m thick, consisting of extremely poorly sorted deposits of clast-supported angular lithic lapilli and blocks (up to 1 m in size), mainly formed by schists. We primarily interpreted the eruptive units as extensive pyroclastic density currents with subordinate very proximal fallout deposits, which overall, cover a minimum area of 15km^2 (on land) with a maximum runout of 7 km from the inferred source. We believe that this represents one of, if not the greatest, phreatic events known worldwide. Further analysis is needed to better understand the main factors controlling the preparatory state of both fluids and the host reservoir, as well as the priming mechanisms leading to such large-scale eruptive events.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

Investigating conditions for gas-driven volcanic eruptions based on Whakaari Volcano, New Zealand

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Gas-driven eruptions are one of the most common types of volcanic eruption in New Zealand and are notoriously difficult to forecast. Forecasting efforts can benefit from holistic, model-driven approaches that investigate a system's evolution and physical state prior to eruption, particularly when combined with multiple types of monitoring data. Our approach is built on two key components: a forward model that explores potential pre-eruptive conditions, and an inversion technique that can find which conditions best fit observed monitoring data. Using this workflow, we have developed heat and fluid flow models and coupled them with degassing and deformation data. Firstly, we investigated rates of heat and fluid flow from magma to the surface in 2D using CSMP++ software. We then used Waiwera software to explore near-surface (< 2 km depth) 3D permeability and heat flow conditions associated with pressure build-up. These models show that reduced permeability within a volcanic edifice, likely due to hydrothermal mineralisation, is a key factor for overpressure that could lead to a gas-driven eruption. Our next step is assimilating gas flux, ground temperature, and deformation data from Whakaari Volcano into coupled Waiwera-PyLith models using the Ensemble Kalman Filter (EnKF). This uses an evolving Monte Carlo suite to investigate how changes in hydrologic conditions and magma-derived fluid flow rates change the system's pressure, temperature, and stress state and the associated monitoring signals. This process will provide insights into volcano-hydrothermal systems prior to gas-driven eruptions, and has potential as a monitoring tool to aid holistic interpretation of monitoring data.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

Modelling the ejection velocity of ballistic blocks based on shock tube experiments

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Explosive eruptions produce pyroclasts of various sizes. In explosive eruptions such as Vulcanian eruptions, some large blocks are ejected, fly into the air, and finally deposit on the ground near the vent. These blocks are called ballistic projectiles or blocks. The size distribution of ballistic blocks varies with the distance from the vent, sometimes from large to small, from small to large, or randomly. Such block size variation has not been clearly modeled because the dynamics of the ejection velocity in conjunction with the block size remains unclear. Therefore, we conducted shock tube experiments, ejecting small glass beads of 0.6-2.0 mm in size. We visualized the shock wave structure using Schlieren imaging and filmed the gas and bead movement with high-speed cameras. The ejection velocity near the vent mainly depends on the pressure ratio of the pressure reservoir to the ambient air pressure, and the bead size. Therefore, the ejection velocity can be modeled using these two parameters, although the velocity can be varied with thermal conditions or the nozzle length. We present how the ejection velocity depends on the pressure ratio and the bead size. A model of ballistic ejection velocity is suggested based on the experimental results. Furthermore, we show how the trajectories change with the numerical model taking into account the ejection velocity variations.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

HYDROTHERMAL ERUPTIONS AT THE DOMUYO GEOTHERMAL FIELD, ARGENTINA: ERUPTIVE DYNAMICS AND CONTROLS

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Hydrothermal eruptions are explosive events driven by the sudden and violent vaporization of the water present in many geothermal fields worldwide. Over recent years, different thermodynamical conditions of fluids and petrophysical-geomechanical features of the host-rocks were mentioned as responsible for the wide range of eruptive styles and deposits generated by hydrothermal eruptions. Nevertheless, geological and historical records show that PDC and fallout processes are underestimated as common processes linked to hydrothermal eruptions. The pristine Holocene–historic hydrothermal eruptive record of the Domuyo Geothermal Field (Patagonia, Argentina) shows a series of contrasting eruptive scenarios. They are characterized by ballistic ejection, PDC and/or fallout deposits, each with a distinctive tefra-composition and granulometry, associated with both excavational and/or aggradational landforms. In this contribution we analyze and discuss how diverse eruptive dynamics are controlled by reservoir energy, depth of the explosion/fragmentation levels, physical properties and structural anisotropy of the host-rocks and eruptive center migrations. This case study is useful not only for the assessment of volcanic hazards associated with geothermal fields, but also contributes to the overall knowledge of the eruptive dynamics and controls influencing this kind of eruption.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

TEN YEARS BENEATH RINCÓN DE LA VIEJA: SEISMIC AND ERUPTIVE INSIGHTS FROM AN ACTIVE CRATER LAKE

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The only active volcano in the northern region of Costa Rica, Rincón de la Vieja is a complex stratovolcano, with 9 cones, one of which is active. The active crater of Rincón de la Vieja has a hot hyper acidic crater lake, with historical records of phreatic, phreatomagmatic and magmatic eruptions. A new eruptive period began in 2011, with the sporadic occurrence of phreatic and phreatomagmatic eruptions including the generation of 21 hot lahars that have descended the northern flank of the volcano. Since 2020, there has been a significant increase in the magnitude and frequency of eruptions, with the most energetic ones occurring in 2017, 2021, and 2023. We use continuous data from seismic and acoustic records, in addition to eruption records to compile a catalogue of discrete seismic signals (VTs, Tornillos, banded tremors, VLPs). Using complementary datasets (e.g., ground deformation), we shed light into the dynamics of the magmatic-hydrothermal system over the last 10-years, which transitions from a closed system to pulses of conduit opening, until reaching the lowest lake levels recorded in 20-years in May 2024.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

Hydrothermal Seal Systematics Giving Rise to Gas-driven Eruptions

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Whakaari, Ruapehu and Raoul are three “wet” volcanoes that are prone to recurring gas-driven eruption events. Studies of ejecta produced by these eruptions, along with emissions data and monitoring observables, provide constraints for the development of conceptual and numerical models of the systems. All have lakes over their respective vent regions, with those at Ruapehu and Whakaari being hyper-acidic, wherein the circulating pore fluids are demonstrably in near-equilibrium with sulphate mineral phases. Here fracture permeability gives rise to fumarolic emissions which are typified mainly by CO_2, SO_2, H_2S and HCl gases. Elemental S is ubiquitous in the zones where rising fumarolic vapors encounter pore-resident fluids, whereas convective flow regimes induced by the fumarolic emissions draw cool lake water downward into deeper hot environments. This leads to precipitation of sulfate mineral phases, thereby reducing lateral permeability, and leading to the development of vertical zones of gas accumulation. Pressures in these compressible gas columns are predominantly governed by local hydrostatic pressure, and presence of CO_2 clathrates in fluid inclusions points to the occurrence of pressures in excess of 40 b attained. Such pressures can exceed rock strength, leading to eruption. Raoul Island (Kermadecs), on the other hand, has a convective flow regime situated over a deeper heat source, from which the more aggressive hydrolysis-promoting agents are scrubbed during ascent. Here, permeability is governed by carbonate mineralization, and lesser amounts of anhydrite, wherein focused deposition of these phases occurs in zones of boiling as the altered seawater fluids rise to the surface.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

Modeling explosion dynamics during phreatic eruptions at Campi Flegrei

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Despite their relatively small volume (compared to magmatic volcanic eruptions), phreatic eruptions have proven to be hazardous, due to their unpredictability and significant proximal impact in terms of ballistic ejection and generation of pyroclastic density currents (Ontake, 2014, Whakaari, 2019). In densely populated active calderas, hosting large hydrothermal systems, like Campi Flegrei (Italy), this is especially critical. Therefore numerical modeling is needed to prepare for possible eruptive scenarios during volcanic unrests. We use a three-dimensional multiphase flow model to simulate phreatic explosions. The model describes the sudden decompression of a high-pressure, high-temperature particle-gas mixture (after fragmentation) and the simultaneous ejection of coarse lithic blocks. After the decompression phase, the expanded mixture forms an eruptive cloud and, eventually, pyroclastic density currents. We present a preliminary calibration and benchmark study comparing results of 3D numerical simulations and laboratory experiments of a shock tube with compressed gas and ash samples, with different grain sizes and with initial pressures. In detail, the rarefaction speed and the particle ejection velocity are compared showing good agreement. The influence of the specific energy (as a function of the initial gas content, overpressure and temperature) is investigated to provide an integral parameter characterizing explosion scenarios. Application to phreatic eruption scenarios at Campi Flegrei show that the area affected by ballistics and pyroclastic flows is strongly controlled by the initial specific energy, while changes in temperature and geometry had only second-order impacts. This is aligned with the approximately adiabatic nature of these explosions.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

Challenges in forecasting phreatic eruption hazards during volcanic unrests: insights from La Fossa di Vulcano (Italy) and La Soufrière de Guadeloupe (Lesser Antilles, France)

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Volcanic systems with hydrothermal activity are prone to phreatic eruptions, sudden steam-driven explosions caused by pressurised, high-temperature fluids released with the fracturing of overlying rocks. While usually smaller in scale than magmatic eruptions, phreatic events can be deadly, particularly in densely populated or tourist-frequented sites. Notable examples include the 2014 Mt. Ontake eruption (Japan), the 2019 Whakaari/White Island eruption (New Zealand), and the 2018 Kusatsu-Shirane explosions (Japan). Developing accurate phreatic eruption scenarios is critical for hazard assessment and risk mitigation, requiring numerical simulation to identify potentially affected areas and to quantify impacts. However, a key challenge lies in determining the parameters that govern such scenarios, including vent position and geometry, eruption energy, grain size, and erupted volume. These parameters significantly influence eruption dynamics and material dispersal but are often associated with high uncertainty. Geological and geophysical data provide essential insights into past events and ongoing unrests, aiding in the characterisation of eruption parameters. This study examines the challenges of eruption scenario definition through two case studies: La Fossa di Vulcano (Aeolian Islands, Italy) and La Soufrière de Guadeloupe (Lesser Antilles, France), both of which have recently entered states of unrest. We highlight how parameters uncertainty affects the modelling of eruption scenarios and emphasize the need for integrated geological, geophysical, and geochemical analysis to refine hazard models, ultimately improving risk mitigation in vulnerable volcanic regions.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

Dynamics, scaling analysis, and hazard assessment of volcanic gas clouds at Kolumbo volcano (Santorini, Greece)

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The 1650 CE Kolumbo (Greece) submarine eruption resulted in the deaths of up to 40 people on Santorini (Thera) due to exposure to a cloud of noxious volcanic gases. No ash was reported in the cloud, so the gas release can be inferred to be unrelated to explosive eruption with ash emissions. Based on medical evidence, reversible and lethal thresholds are reviewed for CO_2 and H_2S being the two main threads for volcanic gas emissions at Kolumbo. Expert elicitation indicates significant uncertainty, with probabilities of similar future gas releases ranging in 15-60-90% (5^{th}-50^{th}-95^{th} percentiles) and a 2-17-50% likelihood of the gas cloud reaching Thera. A 4D multiphase fluid dynamics model (ASHEE) is employed to simulate turbulent gas cloud propagation and dilution under scenarios with source and meteorological conditions informed by expert elicitation and ECMWF-ERA5 2005-2016 data. Analytical predictive relationships are then derived through a scaling analysis based on non-dimensional parameters like the Richardson number. Results indicate a 50% probability of the gas cloud reaching Thera, even with a relatively modest volumetric flow rate of 10^3 m^3 s^{-1} and a wind speed half of the average. However, hazardous concentrations (above 200 ppm of H_2S and 10 vol.% of CO_2) along the Thera's NE coast occur only if source gas flux exceeds 10^4 m^3 s^{-1}. Probabilistic integration suggests a 16-17 % likelihood of hazardous conditions, aligning with elicitation-based estimates. These finding enhance understanding of gas cloud dispersion dynamics and volcanic gas hazards, contributing to risk mitigation strategies for affected regions.

Theme: 3. Volcanic processes

Session 3.14: Gas-driven Eruptions: Characteristics, Processes and a dire need for Forecasting

Allocated presentation: Poster

Modeling the priming mechanism of phreatic eruptions

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Phreatic and hydrothermal eruptions are “wet” eruptions in which fluids (mostly water) hosted in reservoirs at relatively shallow depth explode due to the injection of energy from a deeper source, i.e. geothermal heat for hydrothermal eruptions or hot fluid of magmatic origin for phreatic eruptions. This energy increases the temperature of the water contained within the reservoir up to a state in which a sudden pressure drop might result in explosive expansion. Here we propose a physical model of these systems. This model has been developed applying the mixture theory to the Navier-Stokes system of equation, resulting in a system capable of describing the mechanic and thermodynamic evolution of a biphasic (liquid+gas) fluid within a porous medium. A numerical solver for this model has been implemented in a module for the finite element solver Alya (developed in Barcelona Supercomputing Center). The aim of this research is to constrain in a quantitative way the conditions that are necessary for these eruptions to occur, possibly providing a tool for understanding the hazard related to these phenomena

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk [Invited]

How can we forecast eruptions from caldera systems? A case study from Taupō

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Forecasting the likelihood of volcanic eruptions is always challenging but it is particularly difficult at caldera systems. Often these volcanoes have no observed eruptions, and the geological record shows that they can produce a large range of eruption sizes, from lava domes to supereruptions. In 2022 Taupō caldera, New Zealand, entered a period of unrest which featured heightened seismicity and ground deformation. This prompted Taupō's Volcanic Alert Level to be raised for the first time in its history. Along with our colleagues in the NZ volcano science community, it was our responsibility to provide science advice on the likelihood of a range of eruption scenarios. This revealed fundamental gaps in our knowledge of how these systems operate in the lead up to eruption, even for a comparatively well-studied volcano like Taupō. In this talk I will discuss these knowledge gaps and suggest future avenues for research in this critical area.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk [Invited]

Selective decoupling of soil degassing species and heat flux at surface-sealed hydrothermal systems

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Volcanic hydrothermal systems are characterized by enhanced heat and gas fluxes. At “steaming ground”, vapor is transferred through permeable soils to be diffusively discharged. However, presence of impermeable crusts seals the surface, allowing heat transfer by conduction but trapping gas and steam beneath the surface, decoupling heat and gas emission. Area and intensity of emission are thus dependent on near surface permeability. To investigate the near-surface dynamics of fluid circulation and advection at Vulcano (Aeolian Islands, Italy), we conducted a multiparametric experiment aimed at mapping the spatial distribution of heat and gas emission, and understanding how soil properties influence these pathways. This involved the deployment of an integrated array of thermocouples, CO_2 accumulation chambers, multigas and electrical resistivity tomography for periodic surveys during 2020–2024. We find two sealed heat-pipes associated with thermal ground: at the Fossa crater and at Baia di Levante. We map an annular convection cell, with steam fluxes of 300 kg s^{-1} during unrest. Ascending gas cannot pass through the impermeable crust but are channelized towards fumaroles. However, soil CO2 degassing is found beyond the heat-pipes, implying that CO2 scrubbing occurs at a small scale at the crater and the Faraglione area. Permeabilities are ~10^{-15} m^2 around the pipe, and ~10^{-10} m^2 within it, with values as low as 10^{-3} m^2 in localized areas of steaming ground. Our study highlights how a multidisciplinary approach can map the uppermost portion of a heat-pipe, infer pathways of vapor, fluid and heat flow, and quantify mass fluxes through the system.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk

Simultaneous Observation of Host Medium Deformation and Magma Flow in Volcanic Dykes: An Analogue Modelling Approach

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Volcanic dykes are critical pathways for magma, transporting it from deep reservoirs to the Earth's surface, where it fuels volcanic activity. Dyke propagation involves complex physical and chemical processes, including magma flow, rock fracturing, and the elastic deformation of surrounding material. Understanding magma transport within dykes is crucial for advancing knowledge of magma dynamics and the associated geochemical and geophysical signals, which are critical for forecasting volcanic activity and mitigating its impacts. Although direct observation of magma transport in natural settings is not possible, scaled analogue experiments provide a valuable tool for simulating these phenomena in a controlled environment. Several studies have employed laboratory experiments to investigate fluid flow and host rock deformation during dyke ascent, aiming to improve the recognition of monitoring signals that precede eruptions. In this study, we present a novel experimental setup that enables the simultaneous observation of magma flow and host material deformation. To simulate dyke intrusion, we inject fluids into translucent gelatin blocks and use Particle Image Velocimetry (PIV) to track embedded tracer particles, providing velocity data for both the internal dyke flow and the deformation of the surrounding gelatin. This setup is applied to investigate two end-member scenarios of dyke propagation—buoyancy-driven and flux-driven—helping us understand how these dynamics may influence erupted products and generate geophysical signals recorded by volcano monitoring networks. This innovative approach has the potential to enhance our understanding of magma emplacement processes and offer a more detailed view of the physical mechanisms behind eruption-related signals.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk

Incorporating Laser Rangefinders into Lahar Detection Systems

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Mass movements such as lahars (volcanic debris flows) can occur at volcanoes with or without associated unrest and can be one of the most devastating hazards for life and infrastructure for tens of kilometers downstream. Detecting these events as early and robustly as possible is key to mitigating their effects. Systems installed around the world to monitor mass movements commonly use seismometers and infrasound arrays, along with other instruments such as webcams and tripwires. However, lahars have low-amplitude emergent onsets and moving source locations, making their initial detection and characterization with seismoacoustic methods difficult. Here we present results from multiple field tests of a laser rangefinder as a lahar monitoring tool, including successful recordings of small debris flows at an experimental flume and at Mount Rainier (Washington, USA). We find that while the laser rangefinder unambiguously detects these flows with high spatio-temporal precision, spurious recordings in the laser rangefinder data (noise) tend to correlate with high humidity and snow. Therefore, combining it with other multidisciplinary observations, such as seismic amplitudes, will be key in mitigating false detections, particularly during inclement weather. We discuss the capabilities of incorporating this into a real-time lahar detection system as a potential replacement for physical tripwires to provide confirmation of a lahar. These tests produced recordings that have allowed us to calibrate and evaluate lahar detection algorithms at Mount Rainier and served as a successful test for new geophysical equipment that may be useful for detection of lahars worldwide.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk

Does incorporation of irregular bomb shapes significantly influence the outcome of ballistic hazard models?

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Volcanic ballistic projectiles (VBPs) are a near-vent volcanic hazard that can be frequently fatal. A critical component of VBP hazard assessment is the estimation of impact locations; this is often accomplished via physics-based computational models such as Ballista. Drag is one of the most significant physical controls on a VBP's impact location and is in turn controlled mainly by the VBP's shape, represented as a dimensionless drag coefficient C_D. However, little has been quantified about the drag behaviour of molten VBPs (or bombs), which, especially compared to solid blocks, have irregular and often fluctuating shapes. Therefore, we present a case study comparing a modelled distribution which incorporates a C_D for irregularly-shaped bombs to a real-world scenario. Firstly, we quantified the irregularity of bomb shapes. By examining high-speed video of Strombolian eruptions, we define a framework of shape definitions for bombs and a shape-size relationship. Secondly, we measured C_D for realistic bomb shapes. Using 3D-printed models of our bomb shape end-members, we quantify C_D ranges for each end-member in a wind tunnel analogue experiment. Thirdly and finally, we incorporate these results into the Ballista model using eruption parameters matching Stromboli's July 2019 paroxysm. We partition the modelled particles' C_Ds based on the size-shape distribution and incorporate our experimental drag coefficient ranges for each shape. We then compare the simulated impact distribution to the mapped distribution from Stromboli's July 2019 paroxysm and explore the influence of the bomb shape compared to other factors on the VBPs' impact locations.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk

LiDAR as a tool to reconstruct lava tube networks and their role in lava flow emplacement

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Basaltic eruptions can construct complex lava flow fields over days to years. Flow fields comprise an interconnected network of lava channels, tubes, and inflated lava pads that store lava and mediate its transport to the active flow front. Hence, flow-field geometry has a profound influence on the rate of propagation of lava flows and on their hazard potential. Here we investigate the proximal part of a lava flow field produced by the Pu'u'ō'ō eruption of Kīlauea in 2003-4. The flow field is characterized by a series of rootless shields and the lava tubes over which they form. We used hand-held LiDAR, field observations, and an existing airborne LiDAR Digital Elevation Model (DEM), to reconstruct the surface and interior geometry of the drained shields and lava tubes. The drained shields have a large interior void space 10–20 m high and 50–150 m in diameter. Some shields sit over a deeper lava tube which apparently fed their construction. In many cases, interior lobes connect to shallow lava tubes, which feed further shields down-slope. LiDAR reconstructions allow us to characterize the geometry of the transport pathways that developed within the lava flow field, and to relate them the pre-existing topography. The data reveal the complexity of the transport system within the lava flow, and provide the basis for future modelling of lava flow field evolution.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk

Near real-time mapping and monitoring of effusive eruptions and tectonic movements with crewed airborne photogrammetry surveys on the Reykjanes Peninsula, Iceland

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The reactivation of volcanism on the Reykjanes peninsula in Iceland incited extensive faulting in urban areas and eruption of lava flows, both affecting critical infrastructure and civilians. This has called for effective monitoring of a large area (>300 km^2) by the civil protection and geotechnicians. The Natural Science Institute of Iceland conducts routine airborne photogrammetric surveys from a crewed aircraft with a compact aerial system comprising a medium format camera and thermal camera, which allows for rapid installation of the system and rapid mobilization to the affected areas, and the collection of high-resolution nadir (10 to 30 cm) and thermal imagery (1 to 3 m) at elevations of up to 10,000 ft. This method has the advantage of minimizing time of exposure of the surveys at the volcanic areas, and the flights can be executed within one hour, under moderate weather conditions and/or with cloud coverage over 2,500 ft. The data is processed shortly after acquisition, and the results often submitted to government authorities within 5-6 hours. The products range from orthomosaics, Digital Elevation Models (DEMs), maps of elevation changes, maps of horizontal deformations from pixel offset tracking, and maps of thermal images. These allow for mapping the entire lava fields; mapping the progression of the lava flows; quantifying volume, volume-changes and effusion rates; documenting vent migration; spotting active areas and inflating areas within the lava fields; identifying tectonic fractures and quantifying horizontal and vertical land movements; this data of great value for an integrated assessment of the volcanic unrest.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk

Mobile high-resolution CO2 and stable isotope surveys in ambient air using Delta Ray® measurements in an electric vehicle: assessing volcanic degassing hazards in La Palma, Canary Islands

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In November 2021, unusual CO_2 emissions were detected in the neighbourhoods of La Bombilla and Puerto Naos, located on the western flank of La Palma, about 5 km southwest of the 2021 Tajogaite eruption vents. To investigate the dynamics of volcanic CO_2 emissions affecting both neighbourhoods, 27 high-resolution CO_2 and stable isotope surveys were undertaken in Puerto Naos between 19 October 2022 and 22 February 2024 (~ 2,200 measurements), and 17 surveys in La Bombilla between 2 March 2023 and 22 February 2024 (~ 700 measurements). These surveys utilized a Delta Ray analyzer mounted on an electric vehicle, enabling mobile measurements at 140 cm above ground level. The Delta Ray is a cutting-edge mid-infrared isotope ratio infrared spectrometer (IRIS) that simultaneously measures $\delta^{13}C$ and $\delta^{18}O$ in CO_2 with a precision of 0.05‰. In Puerto Naos, CO_2 concentrations ranged from 420 to 4,500 ppm, while $\delta^{13}C$-CO_2 values varied from -9.0 to -2.7 ‰ vs. VPDB. In La Bombilla, concentrations were slightly higher, ranging from 420 to 8,000 ppm, with $\delta^{13}C$-CO_2 values between -8.1 and -0.7 ‰. Analysis revealed that higher CO_2 concentrations in both areas were spatially associated with $\delta^{13}C$-CO_2 values less depleted in ^{13}C, indicative of a volcanic origin. These findings underscore the utility of stable isotope surveys in assessing the impact of volcanic degassing on air quality and identifying hazardous zones in populated areas.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Talk

Lava effusion in mountainous terrain generates flow backup and increased inundation

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Many volcanic eruptions occur in high relief terrains featuring narrow valleys, sharp turns, and changes in valley width. In these mountainous landscapes, constrictions in width impact the flow and emplacement of effusive eruptions, with such impacts including lava back-up at the point of constriction. Here, we use analogue materials (golden syrup, glycerol) to model lava emplacement in channels that feature significant changes in their width. We measure the impact of the constriction on the excess fluid inundation (i.e. the excess volume and flow thickness) for a range of volumetric fluxes, channel slopes, and fluid viscosities. Our results indicate that fluid/lava backup can be achieved in at least three ways. (i) Interaction with abrupt changes in the channel wall geometry pose as obstacles and barriers to flow and cause local backup. (ii) To achieve a volumetric flow balance between the upstream flow and the downstream flow within the channel constriction, an increase in flow thickness is required. (iii) When choked flow is achieved within the constriction, increases in upstream flow thickness can be generated. For each of these processes we assess the environmental conditions (e.g., degree of channel confinement) and lava properties (e.g., viscosity) under which they operate for basaltic systems. Future work will apply this framework to basaltic lava flows in representative topography. Our results will aid in interpreting the emplacement history of valley-filling lava flows and the resulting impacts on valley drainage geomorphology, and will support forecasting of lava flow hazards in areas of mountainous terrain.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Development of a simplified method for estimating grain size distribution of pyroclastic fall deposits using image analysis

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The grain size distribution (GSD) of pyroclastic deposits provides insight into the processes of fragmentation, transport, and deposition of explosive eruptions. Sieving and laser diffraction methods are quick and straightforward methods for determining GSDs. Unfortunately, these methods cannot handle the weathered fragile deposits and weakly-welded tuff. Image analysis offers a potential solution to these limitations. However, the technical challenges and accuracy of the image analysis remain unclear, as only a few cases have been studied using this method. To evaluate the applicability of the image analysis to pyroclastic fall deposits, we compared the GSDs obtained by the image analysis with those obtained by the combined method of sieving and laser diffraction applied to the same pyroclastic fall deposit ejected from Tarumae volcano, Japan. Compared to the GSDs obtained using the combined method, those from the image analysis were either similar or shifted toward the coarser side on the histograms. The difference in median grain size between the cases with the image analysis and combined method shows a clear trend: the coarser sample, the larger the discrepancy. To correct these discrepancies, a stereological analysis was performed using “ImageJ” and “CSD corrections” to estimate the 3D GSDs from 2D images. The discrepancies between the estimated 3D GSDs and those obtained by the combined method were successfully reduced. In conclusion, this study not only identified the systematic discrepancies of GSDs between the image analysis method and combined method, but also presented a simple method to successfully correct these discrepancies using existing applications.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Mogoșa, a Miocene composite volcano in the East Carpathians (NW Romania) generated by long-lived dome-building activity

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The Gutâi Volcanic Zone in north-western Romania is part of the Neogene volcanic arc of the fold-and-thrust belt of the Carpathian-Pannonian Region of Europe. It consists of a number of more or less eroded volcanic structures and unroofed shallow intrusions. Mogoșa is one of the most well-preserved volcanic edifices whose eruptive history and structure were unraveled by geological mapping and analytical investigations of a representative number of rock samples (radiometric dating, petrochemistry and mineral chemistry). Its volcanic products show a remarkably homogenous basaltic andesitic composition across an unusually long time-span of activity (1.8-2 My), erupted from a deep crustal (25-33 km near MOHO limit) magmatic plumbing system. The small-sized Mogoșa composite edifice (9 km across) is basically a compound volcanic dome system, built up of a number of successive dome-generating effusive events, interspersed with episodes of phreatomagmatic explosions and dome-collapse events generating volcaniclastic deposits at the lower slopes. A number of 4 dome-forming events have been readily recognized and mapped generating an edifice composed of a succession of partially or entirely overlapping extrusive domes. Actually, more domes were emplaced during the long-term volcanic evolution, since dome-collapse-related avalanche-type breccias were identified in the area called Giants Garden, whose original source was probably destroyed or completely buried by later effusive phases. Phreatomagmatic deposits identified at the edifice peripheries along with hydrothermal pipe breccias at even lower topographic exposure levels strongly suggests that the eruptive history of this volcano is more complex than just a succession of dome-generating eruptions constrained in a relatively small space.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Aeolian remobilisation of volcanic ash: What do we know, What do we need?

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Explosive volcanic eruptions can disperse large quantities of volcanic ash over vast areas. After initial deposition, ash grains can undergo aeolian remobilisation, a critical process within the life cycle of volcanic ash. Loose pyroclasts smaller than 500 μm are susceptible to being lifted by wind, with those smaller than ~ 70 μm able to become suspended under certain environmental conditions, and traveling hundred, or even thousand, of kilometres before eventually re-depositing. These intermittent but long-lasting phenomena can have significant and prolonged impacts, including health problems, aerial and terrestrial traffic disruption, damage to agriculture, and social discomfort. Accurate forecasting of these events remains a major challenge, and eruption false alarms continue to be a significant concern for monitoring institutions. Here we evaluate current field and laboratory approaches to quantify the physical parameters required to improve the description of aeolian processes and ultimately develop more reliable forecasting models of aeolian ash. Current approaches on field mapping, sample collection, particle characterization and laboratory experiments are discussed within the framework of a multidisciplinary approach integrating the aeolian dust/sand transport theory and physical volcanology. Finally, we evaluate current practices to identify the gaps where further research is needed.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Investigating vesiculation and crystallisation in volcanic systems: what we have learned in the last 10 years by combining 4D experiments, models and natural observations

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Vesiculation and crystallisation play a fundamental role on magma dynamics and transitions in eruptive style in volcanic systems. They are time-dependent processes that introduce strong non-linearity into conduit flow dynamics, requiring real time studies to investigate such a dynamic system. In addition, vesiculation and crystallisation occur in a 3D system that cannot be quantified via snapshot experiments and/or 2D measurements. To better understand magma ascent and eruption dynamics at mafic volcanoes, in the last decade we have conducted series of 4D (3D space+time) experiments targeting crystal nucleation and growth and vesicle growth and coalescence at realistic magma storage and conduit conditions. The experiments were performed at two synchrotron facilities, DLS in the UK and ESRF in France, combining fast X-ray microtomography/radiography with experimental apparatus capable of reaching high T (≤ 1200°C) and crustal P (≤ 180 MPa), and using mostly the 2001 Etna and 2021 La Palma eruptions as case studies and their products as starting material. By implementing the tomographic data into a numerical model of the physical behaviour of magma in volcanic conduits, we were able to illustrate several mechanisms that control magma transport and eruptability, including crystallisation and dissolution kinetics, dendritic crystallisation and role of vesicle coalescence on degassing/outgassing. In this contribution I will provide an overview of the main results obtained, the scientific and technical challenges involved, and some perspectives on future investigations.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

STRUCTURAL CONTROL ON ACTIVE VOLCANOES: A TOOL TOWARDS AN IMPROVED UNDERSTANDING OF VOLCANIC DYNAMICS AND MONITORING DATA

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Understanding the structural control on active volcanoes is key to analyze the locations and characteristics of volcanic activity and to evaluate the potential associated hazards. For this reason, the Observatorio Argentino de Vigilancia Volcánica (OAVV) has been working on the development of a structural control database for the active volcanoes of Argentina. To achieve this goal, we have carried out an analysis combining two different approaches: (1) at the scale of volcanic edifices, based on the distribution of morphostructural lineaments detected in a high-resolution DEM; and (2) at a detail outcrop-scale, based on structural characterization and the measurement of kinematic indicators. The mesoscale morphostructural lineaments define domains, which can be associated to regional or local faults, or directly represent zones with high fracture density. Moreover, the outcrop-scale survey allows fault zone characterization, while the inversion of kinematic indicators allows us to define a local stress field. The combination of both analyses defines areas of potential structural damage that are susceptible to volcano-tectonic processes, that allow the ascent of fluids outside the main volcanic vent. At the moment, we have defined a new structural context around Copahue volcano, the preferential structures for the ascent of fluids on Planchón-Peteroa Volcanic Complex, and proposed a new structural model considering the stress regime at Laguna del Maule Volcanic Complex. Also, the integration of structural data, alongside conventional monitoring techniques (seismology, deformation, fluid geochemistry, among others) has proven to be an effective tool, allowing a better interpretation of magmatic-hydrothermal fluid dynamics.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Mechanisms of degassing: inducing magma vesiculation via impact

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Volatiles drive magma ascent and volcanic eruption style. As they exsolve from supersaturated melts during ascent, they form a porous network that may “fossilise” into the cold lava counterpart. Our understanding of gas overpressure as a driving force behind eruption dynamics directly relies on our interpretation of these remnant porous networks. Are those networks only capturing decompression driven vesiculation? Can other mechanisms also force magmas to foam and thus contribute to the final porous network geometry? For example, can external, rapid stress perturbations (such as those observed during earthquakes, or during impact of ballistic ejecta) also trigger vesiculation? We conduct a series of experiments on obsidian samples from Newberry Crater, Oregon and Long Valley Caldera, California, employing a newly designed drop tower apparatus that allows impact testing of material at high temperatures. The sample’s thermal properties were analysed to constrain a temperature window above T_g but below their vesiculation temperature at atmospheric pressure. We then bring the samples to temperatures below their vesiculation temperature and impact them at different impact energies. We show that impacts serve as a possible mechanism to induce exsolution of volatiles from the melt by introducing kinetic energy to the system. We further quantify the effect of impact energy on intensity and behaviour of vesiculation. Our findings have implications on interpreting eruption trigger and dynamics as external, rapid stress perturbations are a viable mechanism for volatile exsolution at any level in the plumbing system but also in the plume and ballistics.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Crater Rims or Graben Faults? Ground-Penetrating Radar Insights into the Eldgjá Canyon Formation, Iceland

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Comprehensive models of volcanic deposit distribution can be built by correlating Ground-penetrating radar (GPR) data with geological and stratigraphic observations. GPR has many applications in geophysical and geological research. However, its use for studying volcanic deposits remains underdeveloped. The unique nature of volcanic materials poses challenges in interpreting radar profiles, and therefore, developing a standardised method for applying GPR methodology to volcanic materials is preferable. The Eldgjá eruption, part of Iceland's Katla volcanic system, stands out as one of the most notable explosive basaltic eruptions in historical times, occurring in 934 CE. The Eldgjá fissure is one of the largest in Iceland, located in the southern Icelandic highlands. However, the proximal vent deposits are unclear about the vents, particularly within the Eldgjá Canyon. GPR offers a potential for characterising and mapping the proximal Eldgjá eruptive units. Are the canyon walls crater rims or graben faults, as suggested by some previous researchers? To achieve this, traditional fieldwork observations and GPR surveys were conducted during the summer of 2024. The GPR successfully mapped various volcanic units in key locations such as the Eldgjá Canyon and Skælingar, ranging from proximal tephra fall to fire fountains deposits, with the latter varying from spatter and lapilli to rheomorphic lava layers. Field calibration of the GPR indicates proximal fire fountain deposits that rapidly thin 30-40m from the cliff edges within the Eldgjá Canyon. Accordingly, we propose that these cliffs are not graben faults but rather the crater rims of the Eldgjá 934 eruption.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

UAV magnetic surveys to enhance observational capabilities at Mt. Etna and Vulcano Island

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Magnetic field measurements are a powerful tool in volcanic contexts to characterize the main structural features and image thermal anomalies and intrusive systems. However, in rugged, inaccessible and/or risky areas, magnetic surveys have always been challenging, since they traditionally involved walking with a ground-based magnetometer or flying a de-magnetized helicopter. The first option is slow, time-consuming and may pose a high safety risk to operators, while the other, although faster, is particularly expensive. Recently, unoccupied aerial vehicle (UAV) and airborne magnetometers have emerged as new technology to gather, productively and economically, high-resolution magnetic data. Magnetometer-equipped drones are able to fly at low altitudes covering efficiently wide areas and providing in great detail a map of magnetic anomalies and underlying geological features. Here, we report aeromagnetic surveys recently conducted by UAV at Vulcano Island and Mount Etna. The airborne surveys were conducted using a DJI Matrice 300 with a MagArrow sensor, a laser pumped cesium total field scalar magnetometer, collecting magnetic data at a 1000 Hz synchronized on-board GPS (1 Hz sample rate). The comparison between the magnetic maps obtained by the UAV surveys and those achieved by ground surveys previously carried out in the same area by an Overhauser GSM magnetometer (0.01nT resolution) demonstrate the cost-effectiveness and accuracy of using magnetometer-equipped drones for mapping the inaccessible and rugged terrain and consequently the chance to improve the magnetic surveying capabilities.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

In-situ evidence of ash aggregation during volcanic cloud sedimentation

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Explosive volcanic eruptions are commonly associated with significant ash emissions, resulting in widespread impacts. Volcanic unrest can also result in low-intensity activities that are often neglected, with understudied hazards and processes. This study investigates mild volcanic plumes and clouds (< 2 km above vents) produced in November 2023 at Sakurajima volcano (Japan) and characterized thanks to high-resolution videos captured from distant sites. Associated ash fallouts were sampled and analyzed in situ by combining ground- and drone-based approaches (ash trays and collectors, disdrometer, optical particle counter). This multi-disciplinary approach first reveals that ash aggregation occurs even from mild explosive activity. Grain componentry and size distribution from airborne samples in altitude show the presence of fewer and smaller aggregates compared with samples at ground levels. This indicates that ash aggregation mostly develops during sedimentation, as particles with different settling velocities collide and stick during their fall. Furthermore, sampling under different atmospheric conditions highlights that high relative humidity enhances particle aggregation efficiency in the form of accretionary pellets, instead of particle clusters during dry conditions. This study provides the first in-situ airborne-based measurements for volcanic ash aggregation. It supports previous field, experimental, and numerical investigations on the origin of the different aggregate types, which is crucial for predicting volcanic ash dispersion.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Building a modular, cost-effective visible-wavelength camera network for volcano monitoring

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Monitoring and forecasting volcanic plumes are crucial for detecting, characterizing, and assessing associated hazards. However, advanced monitoring tools, such as thermal cameras, can be expensive and unavailable in many monitoring networks. To address this, a cost-effective visible-wavelength camera network has been developed to capture high-resolution imagery for volcano monitoring. This network provides continuous, automated image acquisition from different locations around a volcanic edifice. Each camera node is equipped with a Raspberry Pi 4 Model B, a Raspberry Pi Camera Module 3, and a water- and dust-proof box for deployment in challenging outdoor environments, with an estimated cost of approximately 75 USD per unit. The system supports diverse configurations, including adjustable capture intervals and resolutions, to meet various observational needs. The network adapts its operation based on environmental conditions, automatically selecting the shutter speed during daylight and using specific settings at night. Images are transferred daily to a server for archival and analysis. Initial tests conducted at Mt. Etna (Italy) demonstrate its reliability in capturing images over extended periods under variable lighting and weather conditions (e.g., high temperatures, rain). The network can also be easily used as a temporary system for field campaigns. By using open-source hardware and software, this camera network provides a flexible, accessible tool for researchers. If paired with GSM connection, and solar panels or battery packs, the system can potentially be integrated into multi-sensor monitoring systems also in remote areas.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Innovative and cost-effective instrumentation to study volcanic ash remobilisation by aeolian processes: application at Copahue volcano (Argentina)

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Volcanic ash can be remobilised long after deposition, particularly under favourable conditions such as low soil moisture and sparse vegetation. This generates secondary hazards that broaden the duration and spatial extent of primary hazards, with potential adverse effects on public health, agriculture and transportation. Whilst it is generally understood that aeolian remobilisation depends principally on the characteristics of ash deposits (e.g., volume, grainsize, density) and environmental conditions (e.g., wind friction velocity, precipitations), its temporal evolution remains poorly characterised in the field. Here, we present a new instrument to study aeolian remobilisation *in situ* using inexpensive collectors and sensors. The setup consists of three wind erosions samplers built from PVC tubes (Méndez's Traps) placed at increasing heights above the ground and coupled with a variety of electronic sensors. This includes temperature, relative humidity, particulate matter (PM), and soil moisture sensors, as well as weight sensors to track the accumulation of material in the samplers, anemometers, and cameras. Arduino microcontrollers are used to enable continuous, autonomous measurements over prolonged periods. The system was first deployed at Copahue volcano (Argentina) in February 2025, where a network of instruments was installed. Regular data and sample collection form part of a citizen science initiative involving local stakeholders, enhancing both scientific insights and community engagement. Preliminary results reveal the existence of temporal and spatial variations in aeolian processes. Long-term PM monitoring also supports air quality assessment in Caviahue, a community located ~10 km southeast of the volcano in the direction of prevailing winds.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Measuring gas and aerosol fluxes with multispectral TIR image data: Bridging the gap between ground and satellite scales

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Orbital multispectral IR instruments are used routinely to derive gas and ash fluxes from volcanic eruptions (e.g., ASTER, MODIS, SEVIRI). The same approach remains difficult to implement in ground-based instruments, due to challenges associated with deployment, maintenance and complex viewing geometries. High-resolution IR spectrometers (OP-FTIR) are also routinely used to quantify gases and particulates at the source. However, these instruments are relatively bulky, only sampling plumes in one location, and must be combined with other data sources to constrain flux information. Multispectral IR imagers can offer a comprehensive solution albeit at a lower spectral resolution, providing the spatial and contextual information necessary to calculate fluxes. In this work, we assess the capacity of a new multispectral IR imager to quantify gas emissions from volcanic sources. The MMT-gasCam acquires images in 12 spectral channels between 8 and 12 μm, with a sampling frequency of ~ 1 Hz. We test an iterative forward model algorithm to retrieve $SO_2$and sulfate aerosols using data acquired at three Italian volcanoes with varying levels of activity: Etna, Stromboli and Vulcano. We contrast the results with brightness temperature difference (BTD) methods, similar to those used for satellite retrievals. Although computationally much faster, BTD methods target individual plume components and produce ambiguous results that are difficult to interpret on the complex proximal plumes. Information gathered from multispectral ground-based instruments can help understand the link between source and distal plumes, a key factor to correctly interpret monitoring signals with future higher resolution IR orbital sensors such as SBG.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Decoupled gas bubbles and lava ponding: decoding the drivers of lava fountain dynamics and evolution through analogue laboratory experiments

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Lava fountains are a common feature of mildly explosive basaltic volcanism. Their behaviour is influenced by the exsolved gas content in the rising magma and by the depth of lava ponding at the vent. Understanding this behaviour is of interest because it provides insights into subsurface processes and dictates the hazard lava fountains pose to those at-risk, such as volcano tourists. In this presentation, we share the results of analogue lava fountain experiments in which gas is injected into water flowing up a pipe, feeding a fountain. We explore how gas content, liquid flux, and depth of liquid ponding over the vent affect fountain dynamics. The injected gas forms discrete bubbles that rapidly ascend through the liquid column, greatly increasing both average fountain height and the amplitude of height fluctuations, resulting in unsteady fountaining. The presence of decoupled bubbles also qualitatively increases the degree of fragmentation of the fountain. On the other hand, we observe that increasing the depth of ponded liquid over the vent reduces both fountain height and fragmentation. Fountain steadiness remains largely unaffected by ponding, depending primarily on the gas volume fraction, as for the un-ponded case. Based on these results, we propose that the behaviour of natural lava fountains is a consequence of: 1) gas organization in the subvolcanic plumbing system, with decoupled gas bubbles driving pulsations; and 2) progressive ponding of lava retained within growing vent structures, which contributes to the gradual suppression of fountaining and volcanic activity.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Analogue experiments to show the effect of buoyancy on surface deformation amplitude above an inflating magma chamber

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At active volcanoes, observed surface deformation results from the complex interaction between the magma and the host rock in the magmatic plumbing system. One common source of deformation is magmatic recharge, resulting in pressurisation of the magma chamber. All active systems, from the most basaltic to the most silicic magmatic composition, are subject to magma chamber replenishment. However, the variation of magma composition implies a variation of its density. In the case of silicic magma, the density can further be decreased by the gas exsolution that occurs at shallow depths. However, the majority of numerical models used to invert surface deformation focus on the effect of over-pressure and neglect the effect of the fluid buoyancy. We present here experiments investigating the effect of buoyancy on surface deformation. Surface deformation, the shear strain pattern and the chamber overpressure are measured throughout the injection of liquid at constant volumetric flux. Then, we use the McTigue (1987) model to predict the surface displacement from the measured overpressure in the chamber, and conversely. We show that predictions are about 7% below the observation when the liquid buoyancy is positive ($\delta\rho$ =-81 kg·m-3) and 9% above it when the liquid buoyancy is negative ($\delta\rho$ =-157 kg·m-3). Even if the effect of buoyancy is small, this highlights the possible error made on source overpressure when inverting surface deformation. This call to a careful consideration of the geological context in unrest period at active systems when volume change needs to be precisely estimated.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Characterising the tensile strength of volcanic rocks at a broad range of strain rates

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K.Brauneis@campus.lmu.de * Mechanical failure is ubiquitous to any geological process in the Earth’s crust and thus occurs at a wide range of deformation rates. Most studies looking at how rocks fail in tension are limited to a small strain rate range (e.g., 10^{-5} 10^{-3} s^{-1}). Here we selected 3 rocks with varying porosities (ca., 2 – 25%) from which we prepared 38x19 mm Brazil discs. We use a uniaxial press and a drop tower to characterise the tensile strength of volcanic rocks at strain rates from 10^{-5} to 10^{3} s^{-1}. While the uniaxial press can bring the sample to failure at constant rates of 10^{-5} – 10^{0} s^{-1}, we estimate the strain rate in the drop tower by dropping an impactor, with an added mass ranging from 0 – 30 kg, from different heights. We evaluate our results considering current empirical laws that aim at estimating the tensile strength of rocks as a function of porosity.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

FORCE: The United States' Newest IHPV Laboratory

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The Facility for Open Research in a Compressed Environment (FORCE) is a new research laboratory at Arizona State University where the volcanology community can access a newly designed, state-of-the-art internally heated pressure vessel (IHPV) designed by Wille Geotechnik. “Nebula” will provide large volume capabilities to pressures of 600 MPa up to 1250 °C for experiments relevant to the volcanological community, including studies of magma storage conditions and volatile solubility. FORCE also provides large volume, high pressure devices previously only accessible outside of the United States. These apparatuses can be used to investigate conditions equivalent to depths up to Earth's mid-mantle. The 500 ton high pressure torsional press “Twister” provides high pressure shear deformation at up to 6 GPa and 200°C. The 6000 ton Kawai-type multi-anvil press “Ichiban” allows for synthesis of ultra-large volume samples up to 25 GPa and T up to 2000 °C. The 1500 ton DIA cubic press “Jasmine” will provide pressures from 25 GPa up to perhaps 80 GPa and up to 2000 °C.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Towards real-time quantification of tephra fallout deposits using optical disdrometers

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Explosive eruptions generate tephra plumes that may impact human populations, infrastructures and air traffic at various time- and space-scales. The forecast of the impact zones in the atmosphere and on the ground of these plumes relies on the quantification of the eruption source parameters (e.g., mass eruption rate; MER, plume height and Total Grainsize Distribution; TGSD). While multi-sensor strategies are used to determine MERs and plume heights, real-time estimates of the TGSD are rare and difficult to obtain. A solution to the lack of such data is the use of optical disdrometers which provide numbers, sizes and settling velocities of detected tephra. We tested the Laser Precipitation Monitor at Sakurajima (Japan) in 2019 and 2023, during the 2021 Tajogaite eruption (La Palma Island, Spain) and more recently at Etna in July 2024. Over a size range of 2.5ϕ down to -1ϕ, a linear trend is found between Mdϕ values of grainsize distributions derived from collected samples and disdrometer data. Moreover, an exponential relationship is found between disdrometer- and sample-derived accumulation rates with an excellent R^2 of 0.95. These excellent correlations strengthen the capacity of optical disdrometers to provide real-time data for very different eruptive conditions (from low to high intensity explosive activity). Based on these results, we are now creating the first European disdrometer network dedicated to tephra fallout monitoring at Etna which will aim at quantifying in real time tephra fallout deposits (i.e., grainsize and sedimentation rate) and studying the temporal relations between the plume dynamics and tephra deposition.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Integrated High-Frequency Monitoring of Strombolian Explosions: Insights from Multi-Parameter Time Series Data

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Stromboli volcano provides a natural laboratory for studying dynamic volcanic processes through high-frequency, multi-parameter monitoring techniques. We analyzed over 300 explosions collected between 2019 and 2024 using acoustic, UV, thermal, high-definition and high-speed recordings, acquired both independently and integratedly with SKATE (Setup for Kinematic Acquisitions of Transient Eruptions). Synergetic data analysis reveals distinct degassing patterns, eruption styles, and correlations between acoustic and SO_2 signals and explosion parameters. Explosion-emitted SO_2 masses exhibit spatial variability, with northeastern vents consistently contributing higher gas budgets. Over short periods, explosions maintain vent-specific SO_2 masses aligned with acoustic characteristics, such as peak-to-peak amplitude and mean frequency. Notably, gas-dominated, jets-like events from a hornito demonstrated unique acoustic signatures, linking explosion types with acoustic features. In May 2023, three active vents were dominated by specific explosion types: 1) gas rich, with low acoustic amplitudes and slow ejection speeds and long duration; 2) bomb-and-ash rich, more powerful with higher amplitudes, lower mean frequencies and larger bomb elevations, and 3) bomb-rich, with intermediate bomb elevation and acoustic amplitude, and lower SO_2 emissions. Despite consistent short-term patterns, long-term vent characteristics exhibit variability, reflecting changes in physical source mechanisms. These findings highlight the importance of keeping a long-term (scale of years) record of high-frequency (scale of seconds) observations in capturing nuanced eruption dynamics. Only the integration of diverse datasets fully highlights the complex interplay between gas emissions, eruption styles, and acoustic features at open vent basaltic systems.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Quantifying compaction deformation of volcaniclastic deposits

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Volcaniclastic materials may compact by gravitational loading under their own weight or due to burial by new deposits, leading to subsidence. We experimentally investigate the compaction of volcaniclastic granules using two lithologies (scoria and hyaloclastite) of different grain size (ash and lapilli). Samples were confined in a cylindrical container, and then compressed between two pistons to target stresses of 2, 5, 10, or 20 MPa, measuring axial displacement. Samples were also loaded and held at each target stress for six hours, measuring additional time-dependent creep compaction. Strain rates were highest during the early loading stages and gradually slowed with increasing compaction as porosity reduction plateaued. Lithology and grain size both influenced compaction, dependent on the relative contributions of (I) grain rearrangement, controlled by size distribution, and (II) comminution, dependent on both size and material strength. Interpolation and extrapolation of the data were used to forecast surface deformation for volcaniclastic deposits of different thicknesses. Here, burial up to 2 MPa (equivalent to a deposit thickness of ~180–230 m) is projected to cause a (near instantaneous) surface subsidence of 24–55 m, with creep adding another ~1–3 m subsidence within less than a year. The findings suggest that compaction may account for significant post-eruptive deformation and emphasises the need to investigate volcaniclastic materials and their properties to improve our assessment of flank instabilities.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Quantitative thermal flux retrievals with multispectral TIR data: Bridging the scale gap.

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Satellite-based multispectral thermal infrared (TIR) instruments are routinely used to derive thermal anomalies and heat fluxes from volcanoes (e.g., ASTER, MODIS, and ECOSTRESS). Similar datasets are challenging to acquire from the ground at high spatial (<5 meters), spectral (>6 bands), and temporal (<1 minute) resolutions, due to constraints related to cost, deployment, and maintenance in volcanic environments. However, if viable instrument solutions are developed, higher resolution observations will be achieved, increasing the potential for the detection of subtle (<1 K and <1 meter) changes in thermal fluxes. Here we evaluate the capability of a new ground-based 12-band TIR imager (MMT-gasCam) to accurately quantify minor thermal anomalies and flux changes at Vulcano and Etna (Italy). Observations were acquired of surfaces within/around each crater for thermal flux retrievals. Subpixel surface thermal anomalies are modeled based on previously developed dual- and tri-channel methods. However, the high resolution of the MMT-gasCam data provides the opportunity to model up to seven thermal components of surfaces. The ground-based analyses are combined with long-term orbital TIR data analyses conducted using ASTER and ECOSTRESS data, to improve the overall completeness of the data record. By combining orbital TIR datasets, it is possible to gain a more complete understanding of the cyclic behavior at volcanoes and start to decipher pre-eruptive thermal changes. These data and analyses provide an opportunity to evaluate the scalability of the algorithms and interpretation for future satellite missions (e.g., LSTM, SBG, and TRISHNA), as well as viability for permanent installation by volcano observatories.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

A framework for ignimbrite analysis methodologies for modelling and hazard evaluation

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Our understanding of pyroclastic density currents has been largely driven by analysis of the deposits they leave behind (and evidence of bypass or erosion). Despite significant advances, there remain fundamental gaps in our knowledge of PDC processes, how these change with time and space, and how they result in high mobility and destructive behaviours. We lack quantitative descriptions to link eruption behaviours and environmental conditions to current processes. There is a disparity between the field data typically collected and the input/output parameters needed for the analogue and numerical models that aim to simulate key processes. Models that test relationships between deposit properties and the currents that formed them are critical, but are hindered by a lack of systematically collected, comparable, quantified field datasets to both inform and validate them. There is a vast literature describing and interpreting PDC deposits, although; (1) there is no consistent approach to characterisation, measurement or sampling of deposits in the field; (2) a proliferation of laboratory techniques has led to increased quantification of sample characteristics, but there is a lack of standard reporting practices, including uncertainty reporting; (3) the highly variable nature of deposits is rarely captured in publications reporting deposit properties. Here we propose a new framework, intended to be a rigorous approach to PDC field data collection and reporting that can be used to inform, benchmark and validate numerical and analogue models. The framework

includes directly comparable, standardised metrics and measuring protocols for quantifying and modelling the sedimentation of PDC deposits.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Shortening wait times for volcano 'blood tests' using a correlative and collaborative hardware solution

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Large-scale deployment of petrological methods during active eruptions is an increasing trend. High-frequency "blood tests"— direct measurements of the magmas feeding an eruption—bring unique insights and forecasting potential. While time-series petrology during active eruptions is now becoming more established, it is still mainly delivered in hindsight, and similarly dense datasets of past eruptions would allow empirical comparison. Petrology is speeding up, yet listening to heartbeats (seismicity), observing breathing (geodesy), and analyzing the breath (gas geochemistry) are widely regarded as the only near-real-time monitoring methods in existence. In parallel, advances in 3D, multi-modal X-ray imaging and rapid 2D chemical and textural analytical methods are defining a new set of opportunities for both syn-eruptive and forensic volcano petrology. An emerging trend is to characterise rocks and minerals and integrate many types of data, which promotes efficient targeting and deeper investigations into high value features. Yet, the instruments required are rarely in the same place, and typically nowhere near volcanoes. A patented software/hardware solution has been innovated to link these trends and deliver "full spectrum blood tests" with reduced turnaround times. The Trækord system (track-record) is a set of mixed-material 3D printed components that include a variety of practical design features. These form bridges between (1) the physical sample and digital data, (2) correlation and calibration between datasets of different dimensionality, and (3) rapid handling and data acquisition across instruments and laboratories. Implementation of Trækord systems is hypothesised to make volcano petrology more accessible, efficient, rapid, collaborative, and, ultimately, more valuable to all.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

60 years of ground deformation analysis at Kīlauea volcano using geodetic measurements and air photos correlation

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Normal faults, extensional fractures and grabens are common features observed at basaltic volcanic islands. They are often associated with volcano-tectonic events such as magma propagation and earthquakes. Here, we analyse the case of the Koa'e fault system, part of the Kīlauea volcano, Hawaii. Magmatic intrusions propagate along two volcanic rift zones, the Southwest and the East Rift Zone, respectively. However, sometimes magma finds barrier and intrudes into the Koa'e fault system (e.g. 1973, 2018 or 2024 event). These intrusions and other volcano-tectonic events cause ground displacement and reactivate specific portions of the fault system. Although this area is monitored by scientists since 1966, we lack a continuous ground deformation analysis over the entire period. Thus, we aim to combine different geodetic methods at different temporal and spatial scale to highlight the fault reactivation during the last 60 years. In the 1965, scientists from the Hawaiian Volcano Observatory installed different benchmarks to survey regularly and monitor the deformation in the Koa'e area using geodetic techniques. Over time, with the advent of satellites, new methods have been developed and continue to advance research striving to achieve more complementary methods. Results show evidence of fault reactivation during four periods, 1973, 1975, 2018 and 2024. We observed different phases of compression and extension at normal faults and propose a simple structural model to explain these deformation types. These evidence reveal important understanding about fault reactivation and fault processes during volcano-tectonic events that involve long-term instability with short term dike intrusions and fault motion.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Understanding shallow magma rheology and eruption dynamics at Volcán de Fuego, Guatemala

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Volcán de Fuego, Guatemala, is a densely populated persistently active stratovolcano, with over 50,000 people living within 10 km of the crater. Recent activity has been characterised by low-level Strombolian to Vulcanian explosive activity, effusive phases, and paroxysmal eruptions. The volcano is monitored by INSIVUMEH using a network of seismic and acoustic instruments, web cameras, satellite observations, along with daily reports from three local observers. The greatest hazard is related to the frequent occurrence of pyroclastic flows during paroxysms, therefore it is crucial to understand the magma properties and pre- and syn-eruptive processes associated with these intense explosive events, as well as the background activity. There is a notable dearth of published data on the rheology of the basaltic to basaltic andesite magmas erupted at Fuego – the high level of volcanic activity and steep slopes represent significant barriers to sample collection. Here, we report the results of high-temperature deformation experiments on a suite of samples collected from the Las Lajas and Cenizas channels in August 2023. Although these samples cannot be tied to a precise eruption date, they are fresh in appearance, cover the range of crystallinity and vesicularity observed in the field, and are assumed to be reasonably representative of the recent range of activity at Fuego (i.e. approximately 5 years prior to collection). We discuss the rheology results in the context of crystal micro-textures and seismic monitoring data to gain insights into shallow volcanic processes and eruption dynamics at Fuego.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

New scientific approaches for understanding lava tube formation and preservation

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Effusive eruptions can generate large lava flow fields reaching great distances from the main vent, expanding along volcano flanks by developing channels and structures whose shape and extension depend on magma properties, topographic features (slope and roughness), effusion rate and emplacement duration. The formation of lava tubes is one of the main causes which determine the further maximum extension of a lava flow. The development of a stable crust around a moving lava, caused by cooling, significantly decreases the exchange of heat between lava and the atmosphere. This phenomenon is extremely significant in the case of volcanoes producing voluminous lava effusions and characterized by a steady effusion rate (e.g. Hawaii and Etna), but it was described also in explosive volcanoes with a lower rate of lava flow production (e.g. Vesuvius). Studies focused on qualitatively describing the development of lava tubes in lava flow fields, but few works examined quantitatively the physical process of lava tube formation and there are even fewer that examine the mechanisms responsible for the formation of lava tubes by multidisciplinary data. Our project TUBES (undersTanding lava tUBe formation and preservation) is focused on a detailed volcanological, petrological, physical analysis, structural analysis (e.g. guided wave analysis, acoustic emission testing) and numerical modeling of the effusive phase of Vesuvius and Etna, focusing on understanding the mechanisms behind the formation of lava tubes. TUBES has the aim to expand our knowledge about the processes at the basis of lava flow emplacement providing information for volcanic hazard and risk assessment.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

The dynamic summer of 2024 at Etna volcano documented by UAS: morphological changes and their gravimetric effects

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From mid-June 2024, the Voragine (VOR), one of the four summit craters of Etna volcano (Italy), entered an unrest phase with mild Strombolian activity. Spatter, scoria, and bombs progressively built up a scoria cone. After two weeks of activity, lava began to flow from VOR towards Bocca Nuova crater (BN). On July 4th, the first of six paroxysms occurred at VOR. The favorable weather conditions allowed for Unoccupied Aerial System (UAS) surveys to be carried out after each paroxysm until the conclusion of this activity on August 15th. The UAS surveys, performed with visible and thermal cameras and a Real-Time Kinematic (RTK) module, enable monitoring the activity, updating the topography, mapping, and quantifying the volcanic products. The availability of a pre-eruption UAS survey (April 2024) allowed us to detail the morphometrical changes in Etna's summit area. Temporal changes in topography also affect the local gravity field. We evaluate the gravimetric effects of the newly extruded masses, i.e., of the spatiotemporal changes of the topographic relief, on gravity and the vertical gravity gradient (VGG). In particular, the VGG is significantly affected by the nearby rugged topography and its changes. Our previous studies show that VGG on Etna reaches quite significant values (we measured -455 μGal/m at the NE crater rim). VGG can be predicted (calculated) based on the gravitational effect of the topography. Such prediction must account for the latest temporal morphological changes. Therefore, we assess the spatial extent and size of the impact of morphological changes on VGG.

Theme: 3. Volcanic processes

Session 3.15: Volcanic processes: from classical to innovative approaches

Allocated presentation: Poster

Disdrometer measurements of tephra fallout from the Tajogaite 2021 eruption (La Palma island, Spain)

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Tajogaite volcano erupted during three months in late 2021 constructing a new scoria cone, and generating destructive lava flows and sustained ash plumes with impactful tephra fallout on La Palma Island (buried houses, roof collapse, traffic interruption, respiratory and ocular discomfort etc). This long-lasting eruption displayed activity fluctuations and transitions at short time scale, with challenging risk assessment and crisis management. In this context, we carried out a field experiment supported by the EUROVOLC project in order to test the application of optical disdrometers for measuring tephra sedimentation and grain size associated with pulsatory activity and to evaluate their potential for operational monitoring during explosive eruptions. Disdrometers powered by batteries and solar panels were deployed in the field to record particle size distributions and terminal fall velocities of ash and lapilli particles. We used a modified Parsivel^2 (OTT, acquiring at 5 s) and a Laser Precipitation Monitor (LPM Thies, measuring individual particles) along with simultaneous ash samples from ground collectors. Both disdrometers were first colocated at <1 km SW from the plume emission vent(s); the LPM sensor was later moved toward SW by 260 m in order to synchronously record more distal fallout. Recorded time series, sedimentation rates, and physical characterization of ash are presented.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Talk

Origin of Basaltic Subplinian Eruption at Shishaldin Volcano (Alaska): A Vigorously Degassing Magma Reservoir Hosting Small Bubbles

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The 1999 basaltic eruption of Shishaldin volcano (Alaska) displayed a transition between Subplinian and Strombolian activity. Strombolian bubbles indicate the presence of a periodically unstable foam at the top of magma reservoir. In contrast, a long foam, whose rupture led to the eruptive column, was also able to collect in the conduit. Laboratory experiments show that long foams can be produced in a conduit by the spreading of a stable foam accumulated at the top of the reservoir. The existence of a Taylor bubble at the onset of the Subplinian phase, also reproduced by laboratory experiments, suggests that the foam in the reservoir was just at the transition between stable and unstable. This constrains the bubble diameter prior to the Subplinian phase to be 0.034–0.038mm when using the foam dimensionless analysis and the underlying gas flux (0.52–0.80m3/s). The increase in bubble diameter and potentially gas flux prior to the Strombolian activity, 0.81–1.4 m3/s, is sufficient to explain the foam in transition to be unstable. The radius of the magma reservoir is small, 200–210 m, as expected. The bubble diameter is the smallest of those estimated for classical basaltic eruptions (Etna, Kılauea, Erta 'Ale), while the gas flux is among the largest. A dilute suspension of small and isolated bubbles cannot explain the large gas flux at Shishaldin. This implies numerous bubbles with a gas volume fraction≥ 0.63−2%, a regime for which the bubbles form bubble clusters. The diameter of these bubble clusters, 3.0–5.4mm, is sufficient to explain large gas fluxes.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Talk

Outgassing behaviour during highly explosive basaltic eruptions

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The low viscosity of crystal-poor basaltic magma typically prevents brittle magma fragmentation. However, highly explosive basaltic Plinian eruptions do occur, presenting a considerable hazard. The explosivity of a volcanic eruption relates to the efficiency in which the gas and melt phases are able to separate during magma ascent. If outgassing is facilitated, an effusive eruption is likely. Instead, if the gas and melt phases remain coupled during magma ascent, a highly explosive eruption may result. Outgassing efficiency is controlled by magma permeability and the development and maintenance of permeable networks within the magma. Yet, estimates of magma permeability from pyroclasts of basaltic eruptions of varying explosivity overlap, indicating a possible complex relationship between permeability, outgassing and eruptive style. We present 3D measurements of vesicle textures, including porosity, connectivity, tortuosity and the throat-pore size ratio for pyroclasts of 3 basaltic Plinian eruptions of the Las Sierras-Masaya and Etna volcanic systems, acquired using phase-contrast synchrotron-based X-ray computed microtomography. We compare our results from Plinian pyroclasts with those from lava fountain activity. We use these data in a 1D steady-state magma ascent model to investigate how controls on magma permeability influence eruptive style, finding that the bubble number density and gas-melt friction largely influence explosivity. However, for fast ascending magmas, gas-melt coupling is maintained independent of magma permeability. In this case, pre-eruptive conditions such as the initial temperature and crystal content have an important role in controlling the transition between a Plinian eruption and lava fountain activity at basaltic volcanoes.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Talk

Fully coupled petrological/thermo-mechanical models of magmatic systems.

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Simulating the chemical evolution of magmatic systems can be done with thermodynamic equilibrium modelling, and recently developed thermodynamic melting models do quite a good job of predicting observations and reproducing experiments for a wide range of compositions. Yet, it is a significant computational challenge as some of the most recent melting models include 11 oxides along with pressure and temperature, which makes this a 13-dimensional Gibbs energy optimisation problem. We developed the parallel software package MAGEMin for this purpose. However, each point-wise thermodynamic calculation still takes 10-50 milliseconds (depending on the complexity of the system). This is too slow if one wishes to directly couple thermodynamic with dynamic simulations of the magmatic system, as those may require 1000's-100'000s of calculations per timestep. An alternative approach is to develop simplified parameterizations from the complete thermodynamic models. That, however, requires recalibration for different scenarios, and gives up some of the predictive power of the models, such as the chemistry of the stable mineral assemblage. We therefore developed a new approach in which we dynamically update a database of precomputed points that only performs new thermodynamic calculations for points that do not yet exist in the database. This significantly reduces the computational effort and allows coupling thermodynamic simulations with thermo-mechanical simulations in a self-consistent manner. We illustrate the power of the method with 2D/3D thermo-kinematic simulations of magmatic systems, as well as by reactive two-phase flow calculations applied to small-scale magma transfer processes in lower crustal migmatites.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Talk

Fault reactivation in extensional regime controlling magma pathways: insights from analogue modelling

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Dike intrusions during rifting events frequently reactivate pre-existing tectonic structures, as observed in Afar (Ethiopia) and Iceland. While surface observations and geophysical methods provide insights into these processes, direct observations of rupture dynamics in the upper crust remain understudied. We conducted analogue experiments to model magma injection and its interaction with tectonic structures in an extensional regime. We simulated extension-induced fracturing and subsequent magma injection under controlled conditions, varying the extension amount and injection rate, using granular materials to represent the brittle upper crust. Our results show that dike morphologies form only when the host rock is under extensional strain, with magma propagation guided by pre-existing fractures. Surface deformations, including graben deepening and uplift, are consistent with natural examples and predominantly accommodated by reactivated faults rather than new fracture formations. Significant strike-slip components (conjugate fault systems) observed at the model surface, near dike tips, show that magma propagation can locally overprint the tectonic signature. These findings highlight the central role played by magma in upper crustal deformation during rifting events, underscoring the interaction between tectonic extension and magma-driven processes. The results have implications for hazard assessment, highlighting the importance of mapping pre-existing structures and their reactivation potential in magmatically active regions.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Talk

Explosive or effusive volcanism at the northern Reykjanes Ridge: the role of magma chemistry

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While mafic submarine eruptions are a main contributor to Earths volcanism, they typically pose a low hazard, due to their limited explosivity at higher depths (1). At shallower depths close to coastal communities, however, explosive eruptions can be a significant threat, but submarine eruptions are rarely observed and therefore understudied. The eruption of Surtsey, south of Iceland, in 1963 is the type-example of a shallow, mafic, submarine explosive phreatomagmatic eruption (2). Also, on the close-by northern Reykjanes Ridge, where the Mid-Atlantic Ridge rises to depths of <200 m towards Iceland, historic explosive eruptions have been reported, e.g. at Nýey in 1783 (3). However, effusive volcanism, in the form of pillow lavas, alternates with these explosive phases and remains the most abundant type of eruptions there (4). During expedition M201 in June 2024, we collected video footage and rock samples from the explosive eruption at Nýey and from an effusive eruption 10 km further south, to evaluate if the products, which displayed different eruptive behaviors, differ in their chemical composition. Here, we will present petrography and the major and trace element data of whole rocks and glasses of these samples, with particular emphasis on elements that can serve as proxy for volatiles, to evaluate the role of the magma chemistry on the explosivity of volcanoes at the Reykjanes Ridge. (1) White et al., 2003, Geoph Monograph (2) Thorarinsson, 1968, Surtsey Res Prog Rep (3) Höskuldsson et al., 2007, J Geodyn (4) Le Saout et al., 2023, Geochem Geophys Geosyst

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Talk

Fragmentation by high energy impacts during volcanic activity

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Volcanic eruptions are amongst the most dynamic and energetic processes on Earth, and yet our understanding of the behaviour of materials under relevant conditions remains relatively limited. Recent technological advancements allow us to experiment at faster, hotter and more extreme conditions with higher precision than ever before, enabling exploration of the failure of rocks across a wide range of loading conditions. In particular, a newly developed high-temperature, high-energy drop tower enables mechanical testing at strain rates up to ~10^3 s^{-1} with impact energies of up to 1,800 J. Here we explore the energy absorption and rupture strength of variably porous volcanic rocks under a range of impact velocities and masses. We find that the peak energy absorbed by a sample at failure decreases with porosity and increases with impact energy. We also show that the maximum energy that can be absorbed by volcanic rocks without suffering irreversible damage depends upon porosity. The peak stress is higher at higher impact energy, and higher than uniaxial compressive strength, due to the rate strengthening nature of rocks. Upon failure a higher proportion of finer grains are produced at higher energy, and more fines are produced upon fragmentation of the stronger, lower porosity samples. The outcomes from material testing using this novel apparatus can provide a quantitative link between the extremely high strain rate rupture dynamics of volcanic materials to the energy budget of volcanic eruptions which to date remains elusive.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Talk

The permeability of transient porous networks in magmas in-situ

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It is well known that the ease with which volatiles can escape magmas dictates the subsequent eruptive style. The volatile escape rate is controlled by both how fast effective pressure (=magmastatic pressure – pore pressure) can build up and how permeable the porous network is. While a huge number of permeability measurements have been performed on cold lavas from volcanoes all over the world, in which the porous network is frozen-in, static, and ‘fossilized’, very few studies have tried to systematically understand the permeability of porous networks in high-temperature magma itself, which by their molten nature are transient and dynamic. Here we use a suite of sintered two-phase (melt and pore) samples, of varying starting porosity, in a novel high-temperature, low-pressure triaxial cell explicitly designed to replicate shallow magmatic conditions. The samples are first brought up to a temperature above their glass transition temperature, allowing for the porous network to evolve as further sintering progresses under 1) quasi-hydrostatic conditions and 2) constant differential stress. During these experiments, the permeability is assessed by keeping a constant pore pressure differential across the sample, and monitoring flow rate. We show that the permeability measured in these dynamic magmatic conditions reflects the architecture of the transient porous network that itself reflects the stress state of the magmatic system. As such, we posit that existing permeability relationships, which require an immutable porous model, likely fail to encompass the full range and transient nature of porous networks in magmas.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Voluminous sediment recycling revealed by Pakistan volcanoes in the Makran arc

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The Makran arc forms by the subduction of the Arabian oceanic plate beneath the Eurasian plate. While the Makran arc features subduction of ~4200 m thick, carbon-rich sediments from the Indus fan, the validity of sediment recycling in this arc has not been tested. Three Late Miocene-Quaternary volcanoes (Koh-i-Sultan, Taftan, Bazman) that are constructed on 46-48 km thick continental basement with variable ages (Paleozoic-Eocene) and compositions provide a unique opportunity to investigate sediment recycling. New ^{40}Ar-^{39}Ar ages, whole-rock elemental and Sr-Nd-Pb isotope data for the Koh-i-Sultan volcano, combined with published data on the Bazman and Taftan volcanoes, reveal for the first time a strong, regional-scale binary mixing trends of Makran arc magmas in Sr-Nd-Pb isotope space and in Th/La vs. Sm/La diagram. The trends suggest an enriched mantle wedge strongly metasomatized by recycled sediments. Within the overarching regional-scale trends, however, the individual volcanic centers display considerable compositional diversity. For example, while individual Makran arc volcanoes plot on a single sediment-mantle mixing trend in Sr-Nd isotope space, their ratios range from MORB-type to those with $^{87}Sr/^{86}Sr$ of ~0.70676 and $^{143}Nd/^{144}Nd$ of ~0.51241. Such isotopic variability can tentatively be linked to the variable sediment thickness along the Makran trench, enhanced by differences in slab dip, convergence rate and trench-to-arc distance. However, the intra-arc variability in the fractionated incompatible trace element patterns (such as Gd/Yb), suggests that the Makran volcanoes were processed in individual ways by partial melting, fractional crystallization and melt mixing during their ascent from the mantle to the surface.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Pathways and Vents of Dyke Intrusion: Insights from Analog Experiments with Silica Powder

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Numerous studies using analog experiments and numerical simulations have explored the mechanisms governing magma intrusion pathways and vent locations, emphasizing the role of edifice loading. Previous powder experiments simulating high-viscosity magma intrusion showed that magma avoids volcanic edifices; however, no study has investigated intrusion from various horizontal positions relative to an edifice. Mt. Usu, an active volcano in southwestern Hokkaido, has a truncated cone shape (ca. 500 m height, with an upper radius of 0.6 km and a basal radius of 3 km). Its eruptions occur at diverse vent locations, including the summit and flanks, with varying eruption styles by site. Even within the summit crater, vent locations show variability. To study the impact of horizontal intrusion positions on magma pathways, we conducted two-dimensional analog experiments using silica powder as the host rock and syrup to simulate high-viscosity magma. A trapezoidal structure mimicking Mt. Usu was placed on the apparatus with intrusion points set beneath the center, edge, and middle of the trapezoid's upper surface. Results showed that magma intruded beneath the center followed a curved path to the upper surface. Magma intruded beneath the middle and edge bifurcated, erupting from both the slope and base. These findings suggest that horizontal positional relationships between the volcanic edifice and intrusion points strongly influence diverse vent locations on Mt. Usu's summit and flanks, while the summit crater exhibits less variation in eruption sites.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Combining Ash Characteristics, Geophysical Data, and Visual Observations to Understand the 2022 Eruption of San Miguel Volcano, El Salvador

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After its 2013 Volcanic Explosivity Index (VEI) 3 eruption, San Miguel volcano has experienced several minor eruptions (VEI 1–2) in subsequent years. One of the most notable occurred from November 15–29, 2022, with more than 190 small Vulcanian eruptions, accompanied by ash emissions and ejected ballistics. Analysis of ash samples collected during the eruption sequence, along with geophysical and visual data, provide insights into this activity. In the months before the crisis, seismic activity was anomalous, particularly episodes of tremor a month before and low-frequency earthquakes in the days prior to the eruptions. However, GPS and INSAR did not record any deformation of the volcano. Seismicity and the absence of deformation could indicate a semi-open or open conduit volcanic system. Ash characteristics reveal the presence of juvenile material, with black, vesicular, angular, and shiny clasts, and golden vesicular clasts, indicating that the eruptions involved fresh magma. Towards the end of the crisis, a change in componentry was observed with a decrease in free crystals and increase in altered angular black material, coinciding with a rise in explosiveness, reaching the maximum heights of the eruptive columns. Volcanic ash fell in nearby communities and for the first time, the impacts on health and the environment were assessed. Approximately 20% of the ash volume sampled on different days contained respirable-sized particles (<10 microns). Furthermore, leachate data from the ash were collected to assess the impacts on water sources for human and animal consumption, as well as on crops in the area.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Volcanic ash erupted at Stromboli before the 2024 paroxysm adds a new piece to the feeding system puzzle

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We present a petrological study of a time series sampled at Stromboli volcano between April 9th and August 3rd 2024. In the observed period, a continuous spattering activity started in early May and caused the rapid growth of hornitos at the North-East vent area. On July 3rd-4th, the intensification of spattering led to the partial collapse of the NE portion of the crater terrace, favoring the opening of low-elevation vents that gave rise to lava flows along the Sciara del Fuoco. The effusive activity culminated in the violent paroxysm of 11th July, followed by the interruption of all eruptive phenomena until the end of July. Studied samples include ash and lapilli emitted both during the ordinary Strombolian activity and paroxysm. SEM-EDS-based chemical and textural analyses of groundmass glasses and mineral phases reveal that ash and lapilli have a different petrological signature. Ash emitted before the paroxysm is characterized by complex mingling textures and compositions that are not detected in the lapilli fragments. Associated compositional trends partially diverges from the typical mixing between the two melts that characterized the Stromboli feeding system, tracing an evolution by mingling and crystallization involving a component derived from the crystal mush. Previous studies detected at least < 3% of deep-sourced magma in the ash fraction erupted during the ordinary activity at Stromboli, while in two ash samples collected in May 2024 we found about 15-20% of clasts with these petrological features, suggesting an increasing of the magma supply from depth at least two months before the paroxysm.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Multi-isotopes (Sr-Nd-Pb-O-B) as indicators genesis of basaltic-andesitic ignimbrites and influence of meteoric-hydrothermal system at Verkhneavachinskaya caldera, Kamchatka

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The present study aims to identify the conditions that led to the formation of the Late Miocene basaltic-andesitic ignimbrites at the Verkhneavachinskaya Caldera (VC), which extends over significant areas (120 km^3, 10x12 km) on the Eastern Volcanic Belt, Kamchatka. New oxygen and hydrogen isotope data indicate that the intracaldera ignimbrites have low $\delta^{18}O$ values, reaching -5.03‰ and - 182‰ δD values. The results obtained imply the presence of a substantial meteoric-hydrothermal system during the cooling of intracaldera pyroclastic flows in the presence of glacial meltwater, which subsequently led to the formation of the ignimbrite sequences of the VC. A comparison of Sr-Nd isotopes indicates the dominance of crustal evolution of the material, while Pb isotope systems suggest a significant contribution from slab fluid. Multi-isotope measurements allowed correlations to be revealed and the role of the meteoric-hydrothermal system to be ascertained.The present study aims to indentify whether elevated Pb-Sr isotope values could be associated with the introduction of these elements by potential sources from the radiogenic Cretaceous basement of Kamchatka. This would suggest a predominant role for the meteoric-hydrothermal system in the evolution of the geochemical characteristics of the VC ignimbrites. Conversely, variations in $^{143}Nd/^{144}Nd$ and their negative correlation with $^{87}Sr/^{86}Sr$ suggest a predominantly magmatic origin for at least some of the observed trends.The observed trend of $\delta^{11}B$ with correlation to Nd isotopes suggests a substantial contribution of slab input to the magma explosivity of the VC.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Cracking under pressure: Investigating ductile failure in magmatic systems

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A critical outstanding question in modeling dike initiation from a magma system is how failure occurs in ductile regions. To better forecast and evaluate the eruption potential of a magma system, it is necessary to understand the rheological processes that control its stability, failure, and rupture, accomplished through understanding temperature-dependent variables. In elastic materials, Young's modulus characterizes stiffness and resistance to deformation. Whereas in ductile materials, the hardening modulus describes how strength evolves beyond the yield point as the material responds to sustained stress. Constraining these mechanical properties is essential for identifying the variables governing dike initiation in ductile regions. At high strain rates, ductile material is hypothesized to behave elastically due to strain hardening, allowing cracks to initiate when stresses increase beyond a failure point. However, experimental data to understand strain hardening in ductile materials are limited. In this study, uniaxial compressive strength tests are conducted using welded ignimbrite samples from Yellowstone's Lava Creek Tuff to investigate the thermal and strain rate controls on ductile fatigue and failure. Core samples (19x39 mm, maintaining a length-to-diameter ratio of 2) of fine-grained, rhyolitic tuff are used to represent the host rock surrounding a regional magma chamber. We use a thermomechanical Instron Model 1331 at a variety of temperatures (150-750°C) to investigate the temperature dependence of the unconfined rock's hardening moduli and the failure at high temperatures. The results of this study provide key parameters for modeling magma system evolution and constraining the conditions that lead to dike initiation and eruption.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

The ejection and cooling rate of pyroclasts during mafic explosive eruptions

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Explosive volcanic eruptions pose a threat to nearby populations and infrastructure. Erupted pyroclasts (i.e., variably molten lava droplets) can travel large distances from the eruptive vent to cause a range of hazards. To mitigate these hazards from explosive eruptions there is an increasing need to improve our understanding of the transport dynamics of pyroclasts. In this study, we developed and coupled both a transport and a transient cooling model that account for the instantaneous, in-flight, cooling of pyroclasts of different sizes, launch angles, and exit velocities. The transport model developed solves equations for a translating spherical body in two-dimensional (2-D) space and the cooling model solves the Fourier heat equation for spherical bodies. The two models were then coupled using a set of equations that describe relationships between Nusselt-Reynolds-Prandtl numbers. These relationships provide a way to estimate the heat transfer coefficient, based on ambient flow conditions around the pyroclast, at different times during the particles transport. Together, our model can describe the trajectory, distanced reached, and cooling profiles of pyroclasts during all mafic explosive eruptions. We show how it can be used to predict the temperature of pyroclasts within lava fountains and discuss the possible textural outcomes of ejected pyroclasts in-flight and upon landing. Thus, our model can be used to predict the pyroclast types (e.g., rheomorphic, breadcrusted) at set distances from the vent and used to forensically determine eruptive conditions from deposits of past eruptions. **Keywords:** transient cooling, transport, explosive eruptions, numerical model, real-time monitoring

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Seismo-acoustic monitoring of experimental volcanic fragmentation, fluid-filled cavities and mass flux dynamics

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We performed experiments in a shock-tube apparatus that combined direct observations of rock fragmentation and mass flux dynamics, with a time series parameterization of pressure, elasto-acoustic signals and conduit elastic deformation. These combined observations show that the style of rock fragmentation processes, triggered by rapid decompression, determines the style of conduit dynamics and mass flux behavior. Here, we present visual evidence of the formation and resonance of fluid-filled cavities, and analyze the frequency characteristics and waveforms of the elasto-acoustic signals associated with the dynamics of gas-particle-filled cracks. Our findings indicate that the gas-particle mixtures within cavities transit up and down causing erosion and/or accretion in the lower and upper surfaces that confine each cavity. This behavior induces striking signals with harmonic characteristics that attenuate with time. The distribution of an assembly of cavities determines the architecture of the conduit and modifies the frequency content of the signals. We calculate the crack stiffness curves and the impedance contrast and the resonance modes for the experimental cracks based on the fluid-driven crack model.The spectral characteristics of the experimental signals fit the fluid-filled crack model confirming that the crack model is useful to interpret resonant modes at different scales. The present observations represent a major contribution that help to clarify the source mechanism of signals related to fluid-filled cavities as can be the LP and VLP signals observed in many active volcanoes around the world.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Petrological Analysis of Holocene Tephra from the Antillanca Volcanic Complex, Chile

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The Antillanca Volcanic Complex (AVC) straddles the Chile-Argentina border. Despite its known Holocene activity and its position within the upper third of SERNAGEOMIN's 'volcano ranking' (number 26 out of 92) [1], it remains comparatively understudied, and its hazards not well characterised. Antillanca's last major explosive eruptions, dated to ~2 and 3 ka ago, sourced the Pampa Frutilla (PF) mafic ignimbrite, and the Playas Blanca Negra (PBN) tephra, respectively [2]. We present EPMA data for olivine, plagioclase and hornblende crystals from both deposits and discuss the constraints they provide on magma evolution and storage conditions (derived using MELTS) and on magma ascent during eruption. We consider implications for architecture of the AVC magmatic system and for scenarios of future unrest or activity. *[1] https://magnet.cl (2020). Gob.cl - Article: National Geology And Mining Service Publishes New Volcano Ranking. [online] Government of Chile. [2] Naranjo, J.A., Singer, B.S., Jicha, B.R., Moreno, H. and Lara, L.E. (2017). Holocene tephra succession of Puyehue-Cordón Caulle and Antillanca/Casablanca volcanic complexes, southern Andes (40–41°S). Journal of Volcanology and Geothermal Research, 332, pp.109–128. doi:https://doi.org/10.1016/j.jvolgeores.2016.11.017.*

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Changes in degassing potential within cooling lava domes

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The extrusion of viscous lava domes is often a passive process, but can result in plugging of the conduit and the build up of pressure, causing an explosive event. How easily volcanic gases can move through a lava dome depends on the permeability of the lava and the presence (or not) of large scale degassing pathways. Once lava reaches the surface, it begins to cool, changing its physical properties and state, altering its permeability. Through the use of high temperature experiments, we investigate the impact of changes in these properties on the permeability of samples from Soufrière Hills volcano, Montserrat. During extrusion, internal lava dome temperatures were estimated to around 850°C and measured surface temperatures were reported to be 500-600°C. However, current surface temperatures are near ambient. In addition, the physical properties of the lava extruded over 15 years of eruption have varied significantly. For example, porosity has varied by over 20% over the course of the eruption. Changes in the temperature of the lava dome will alter the potential of gases to move and escape. Permeability experiments at temperatures up to 800°C show that in general, as the lava in the dome cools, permeability increases. Due to differing physical properties, lavas from different phases of the eruption show variations in their response to cooling. Different sections of the lava dome may therefore have different degassing potentials and pathways. This has potential implications for the hazards associated with a restart at volcanoes where recently emplaced lava domes are still present.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

A sticky situation: The heterogeneity and implications of magma mush unlocking

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How can magma be mobilized from a rigid state? Various geochemical and geophysical datasets suggest that crustal magmas spend most of their time close to the solidus as magma mushes, in which the crystal framework makes a magma mush rigid and potentially immobile in the absence of external disturbances. The unlocking of crystal mush due to new magma injections is a ubiquitous process leading up to eruptions but is poorly understood on a micro-mechanics scale. We conduct scaled analog experiments (in a 14 x 6 x 20 cm tank) in a low Reynolds number regime. We utilize corn syrup to represent melt, 4 mm spheroidal plastic beads to represent crystals, and combine the two (~60 vol. % beads) to represent mush. Density differences of ~100 kg/m^3 drive the interaction between two initially distinct mush and melt analog layers. We use time-lapse photography and ML image segmentation to observe changes in the magma mush and melt layers over time. The maximum velocity of mush disaggregation is well-represented by an analytical model based on individual particle displacement at the liquid interface. However, this process of mush disaggregation is highly heterogeneous. The complex morphology of mush disaggregation is markedly different from a uniformly percolating porous media flow front. Our results have significant implications for interpretations of single-crystal geochemical records, such as trace element zonation patterns in zircons. Our results also highlight the key microphysical processes for melt transport through magma mushes and help to illuminate the complex nature of transcrustal magmatic systems.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

The Effects of Stratocone Morphology on Shallow Magma Transport

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Eruptive vent locations at stratovolcanoes, whether at the summit or on the flanks, are determined by the trajectories of dikes as magma ascends to the surface. Previous field studies and analog modeling (e.g., Acocella and Neri, 2009; Harp, 2021; Kervyn et al., 2009; Poland et al., 2008) have contributed considerably to this topic by highlighting how edifices provide a structural control on shallow magma transport. However, understanding the trajectory of dikes within a volcanic edifice is challenging due to the complexity of near-surface stress fields, especially given the large-scale topography of stratovolcanoes. Existing models for crustal stress in volcanic systems are either limited to basement rocks beneath the edifice (Pinel and Jaupart, 2000) or limited to simple topographic features that fail to capture the geometries of stratovolcanoes including breaks in slope and high aspect ratios (height to basal radius). Using a finite element approach, we compute the state of stress in both the volcanic edifice and the underlying crust for a range of edifice morphologies representative of arc volcanoes worldwide. These crustal stress models serve as a basis to examine how edifice morphology modulates shallow magma transport at stratovolcanoes. This work provides a step towards understanding the structural controls on vent elevation at stratovolcanoes.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Eruption scenario and hazard assessment at a basaltic volcanic island: a preliminary result on Gaua volcano, Vanuatu

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Basaltic volcanic islands exhibit a variety of explosive eruption styles, from small-scale phreatomagmatic explosions to large caldera-forming eruptions. The eruptions may become complicated and more hazardous due to interaction between magma and seawater. We focus on Gaua volcano, an active oceanic volcanic island in Vanuatu with a diameter of ~20 km that has a ~8 × 6 km summit caldera. We aim to understand the eruption history, the processes that have produced the various eruption styles, and their impacts, and use these to assess hazards. We present preliminary results, including stratigraphy and chemical compositions of representative deposits, obtained through mapping and sampling at coastal outcrops and at the caldera rim. Some coastal sections in the north are thin and dominated by a scoria lapilli fallout and a lapilli tuff, whereas other coastal sections in the west consist of lava flows and overlying pyroclastic current and fallout deposits. The thickest pyroclastic current deposit (likely derived from a caldera-forming eruption) shows alternating massive and stratified facies, and the stratified facies shows evidence of magma–water interaction such as abundant accretionary lapilli and cross stratification. We also identified several satellite cones along the coast. These small cones indicate that magmatic eruptions occurred near the coast due to the fissure formation reflecting the regional stress field. The new survey results provide insights into the potential hazards associated with large basaltic islands such as Gaua and may help to construct accurate hazard maps that mitigate the impacts of future eruptions.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

The Link Between Petrology and Analogue Modelling: A Global Combination Experimental Study

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Volcanic eruptions pose significant societal and environmental hazards, emphasizing the need for a comprehensive understanding of magma dynamics. This study integrates petrological and experimental methodologies to characterize volcanic processes and potentially aid in reducing volcanic risk. Petrology can provide insights into magma composition, temperature, crystallization, and volatile behavior, while analogue modelling replicates magma transport and eruptive phenomena on observable scales. By combining these approaches, this study bridges the gap between laboratory experiments and natural systems, advancing the understanding of magma feeding systems, conduit processes, and eruption mechanisms. Key research focuses include magma ascent dynamics, dike propagation, and potential shifts in eruption dynamics. The current work for this study is comparing crystal populations in dykes with analogue experiments. These experiments use petrological inputs—e.g. mineral chemistry, melt inclusions, and crystallinity—to constrain parameters like viscosity, density, and volatile content in scaled analogue materials. Preliminary results can reveal insights into magma mixing, degassing, and fragmentation, linking physical processes to petrological features like zoned crystals and volatile gradients. Crystal population dynamics in analogue models and conduit models will also be used to assess the representativeness of diffusion timescales from fast diffusing elements (e.g. H^+ in olivine). Future investigations may target the Lamongan volcanic field in East Java, Indonesia. Volatile analyses and studies of lava dome sizes in relation to eruptive styles further enhance the collective understanding of magma dynamics. This integrated approach offers novel perspectives on volcanic systems, which can support eruption forecasting, hazard assessment, and predictive model development for diverse volcanic settings.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Numerical modeling of joint H2O-CO2 diffusion reveals decompression and cooling history: Application to the IDDP-1 borehole glass

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Numerical simulations of bubble growth have focused on the role of total water in vesiculation. We present a novel model that jointly solves for diffusion of molecular $H_2O$and CO_2, along with reaction between OH-$H_2O_{molecular}$ in volcanic melts along specified pressure and temperature paths. The simulations produce outputs of bubble size, total vesicularity, water speciation and volatile content in the glass with distance from bubbles and the H_2O/CO_2 ratio of the vapor phase. This allows for comparison with multiple observables in natural samples. Combined with constraints provided by geophysical monitoring and geospeedometry, we can constrain possible decompression and cooling paths from source to surface. We apply the model to the IDDP-1 borehole at Krafla volcano, Iceland, which intersected a magma body at 2.1 km depth in 2009. Our model allows for reinterpretation of the cooling and decompression path experienced by the magma in the minutes following contact with drilling fluid, suggesting that storage may have been at higher pressure than previously thought (consistent with lithostatic load). We highlight the role of the different diffusivities of H_2O and CO_2 that 1) produce an apparent delay in bubble growth compared to a water-only system, 2) promote preferential resorption of water during cooling, resulting in a final non-equilibrium vapor phase, and 3) result in volatile profiles with distance that have little or no indication of resorption despite prevalent resorption due to cooling. The numerical model can be applied to many systems via a modular approach for e.g. viscosity, water and CO_2 diffusivity and solubility.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Global mapping of eruptive styles to magma viscosity and ascent rate

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Magma ascent rates (MAR) and viscosity are primary controls of eruption dynamics, to accurately determine either parameter from eruption deposits has proven to be challenging, and almost impossible during eruptions. Combining these two parameters for a large dataset of past eruptions with hindsight can be beneficial to determine the physical processes behind eruption styles, which is key for hazard assessment. Here, we compile magma ascent and decompression rates values from past studies, that we combine with new calculations of melt and magma viscosity for a large number of eruptions with different styles. Our curated dataset includes 222 MAR from 93 eruptions at 46 volcanic systems with magma composition ranging from basalt to rhyolite. These values were obtained using 13 different petrological or geophysical methods and represent 10 eruption styles. We find that for high-viscosity endmembers, eruption styles are bimodal, with plinian eruptions dominating at high MAR and extrusive eruptions dominating at low MAR. The MAR limit between the two domains of Plinian and extrusive decreases with higher viscosity which highlights a strain-rate control of fragmentation. Towards the low-viscosity endmember, controls are less clear, where high MAR still tends to produce intense explosivity (fountaining, plinian eruptions), whereas low and intermediate MAR show high variations of eruption styles from effusive to fountaining. Our dataset demonstrate that no eruption can occur from low MAR and low viscosity endmembers, underlining a condition linked to gas decoupling from ascending magma that prevents it from reaching the surface.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Syneruptive textural mingling as trigger of a Subplinian basaltic monogenetic eruption

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Scoria cones are commonly associated with monogenetic, weakly-explosive eruptions emitting small volumes of magma. However, recent research has shown that these eruptions can be violent as was the case at La Vache and Lassolas. These two monogenetic cones located in the south of the Chaîne des Puys (France) were formed by a complex trachybasaltic eruption 8600 years ago. This eruption consisted of 5 phases: (i) an opening phase, (ii) a Subplinian phase, (iii) a violent Strombolian, main cone forming phase with simultaneous emission of a lava flow, (iv) a last Strombolian activity marked by the arrival of a fresh, gas-rich magma, (v) and a final phase purely effusive. This study combines textural and petrological analysis of the explosive products throughout the entire eruptive sequence and highlights four main results. The feeding system was composed of two reservoirs located at 30 km (near the MOHO) and 12 km, the lowest one being injected by pulses of basaltic magma. A partially degassed and crystallized magma batch close to the surface acted as a plug for the ascent of fresh magma. The explosivity of the eruption was caused by the overpressure in the system when fresh magma met this degassed magma body. Preliminary estimates of the time elapsed between the first magma recharge event and the eruption varies from a few hours to a few days. If such durations prove to be robust, then this type of eruption represents a non-negligible hazard for the surrounding populations.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Understanding the ordinary to forecast the extraordinary: four years of integrated insights into Stromboli's explosive activity and hazard mitigation

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The INGV UNO project (Understanding the Ordinary to Forecast the Extraordinary) adopts a comprehensive, multidisciplinary approach to investigating the Stromboli volcano's explosive activity. In its fourth year, the project made significant advances in four key areas: physical and chemical parameterization of eruptions, textural and petrochemical analysis of eruptive products, morphological monitoring and remote sensing, and data management. Over 15 multi-sensor data acquisition campaigns revealed critical insights into the complex interplay between explosive activity, underlying magmatic processes and morphological changes. Enhanced SKATE systems enabled the collection of high-frequency thermal, acoustic, and UV datasets, yielding refined eruption parameters and correlations among SO_2 emissions, acoustic signals, and eruption dynamics. An automatic sampler allowed high-frequency petrochemical analyses linking magma crystallization and degassing dynamics to variations in eruptive intensity, with new findings highlighting the interaction of high-pressure and low-pressure magmatic components. UAS and LiDAR surveys documented detailed morphological changes at the crater terrace, Sciara del Fuoco and other sector of the island affected by hydrogeological instability with unprecedented temporal detail, producing high-resolution digital terrain models. Integrated numerical simulations advanced hazard mapping for ballistic projectiles. A geospatial database was built for streamlined data storage, analysis, and dissemination. Outreach efforts included citizen science initiatives, fostering community resilience on Stromboli. International collaborations enriched research outputs, which included multiple publications and contributions to major conferences. The results evidenced clear

precursory patterns preceding the two large explosions of 2019 and 2024, providing a framework for studying open-vent volcanoes globally, enhancing preparedness against volcanic risks.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Boudinage: an effective medium to evaluate stress during lava dome growth

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Obsidian Dome and Glass Creek are lava domes erupted around 1350CE along the Inyo Chain at Long Valley Caldera (California, USA). The lava domes exhibit similar chemistries but contrasting crystallinities, which we interpret to have promoted different rheologies and by extension, emplacement conditions. Both lava domes display frequent dm-scale enclaves which have been variably deformed, stretched and ruptured to form boudins within an obsidian matrix. Some boudins reveal sharp boundaries and fractures associated with brittle behaviour, whereas others show undulating edges with pinch out ends we ascribed to partly ductile behaviour. These rheological textures along with the limited extent of shear during and following boudinage suggests that the boudins formed at high temperature late during dome growth; thus, we suggest that boudinage may be an important marker to assess stress conditions during dome growth. We flank our field observations with thermal analysis to constrain the glass transition temperature and cooling rate, and direct pull-tests to quantify the tensile strength of the enclaves at eruptive temperature. We use the dataset to discuss emplacement conditions of these two lava domes.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

What's the speed limit?: An assessment of the decompression rate of the VEI 6 eruptions at Colli Albani and mafic volcanoes worldwide

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The key driver of explosive mafic volcanism remains an enigma in volcanology. One key aspect often pointed to is the role of rapid magma ascent, as rapidly ascending magma allows for the volatiles to remain coupled with the melt. Such is the case for Colli Albani (Italy), a mafic-alkaline caldera complex with seven VEI 6-7 eruptions during its eruptive history. Clinopyroxene chemistry, melt inclusion vapor bubble volume fraction, and volatile contents of melt inclusions point to an initially volatile rich bubble-bearing magma, which was rapidly transported to the surface, resulting in an extremely explosive eruption (Jorgenson et al., 2024). However, a robust quantification of decompression rates is still missing for Colli Albani. Furthermore, the overall relationship between eruption intensity, magma composition, and decompression rate for mafic explosive eruptions is poorly understood in the literature. We collected high-resolution X-ray tomography to characterize vesicle textures, including bubble number density, which can be used as a proxy for decompression rate (Toramaru 2006). We will present a collection of decompression rates from mafic tephra to clarify the role of magma ascent in modulating the intensity of mafic explosive eruptions and develop a framework for the explosivity of the Colli Albani volcano.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Santa Bárbara Volcano (Azores): Ongoing Unrest and Crustal Deformation Observed From GNSS and Seismic Monitoring

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Santa Bárbara volcano on Terceira Island, Azores, has experienced significant unrest in recent years. From 2003 to 2017, Terceira remained relatively stable, with low seismicity and minor subsidence observed in the central part of the island. The unrest started in late 2017, marked by increased seismicity and transient crustal deformation episodes. Currently, CIVISA (Centre for Information and Seismovolcanic Surveillance of the Azores) operates a permanent network of 11 seismic and 13 GNSS stations on the island. A notable increase in activity began in June 2022, initiating a more sustained period of unrest. Seismicity alternated between periods of swarm activity lasting days to weeks and periods of lower activity, but event counts during the latter remained elevated compared to pre-2017 levels. The strongest earthquake, a magnitude 4.5 ML event, occurred on January 14, 2024. That year, seismic activity culminated on December 25, with over 1,000 earthquakes recorded, the highest daily count to date, surpassing the previous peak of about 400 events on June 19. GNSS data from 2023 to 2024 reveal uplift and horizontal divergence of displacement vectors away from Santa Bárbara, consistent with inflation. Modeling the velocity field using a Mogi source embedded in a uniform elastic half-space suggests a volume increase of approximately 3 million cubic meters over one year, located at ~3.5 km depth beneath the southeastern caldera rim. Capturing deformation with Sentinel-1 InSAR data remains challenging due to low deformation rates, atmospheric noise, and dense vegetation, highlighting the critical role of GNSS in monitoring the ongoing unrest.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Explosive phases of the 937-40CE Eldgjá flood lava eruption, Iceland and the variability in magma composition

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The 937-40 AD Eldgjá flood lava eruption in Iceland (21 km^3) took place on a ~70-km-long vent system trending northeast from the Katla central volcano. It features four distinct vent segments: Eldgjá South, Central, Chasm, and North. The South segment is partly beneath the Mýrdalsjökull glacier, but the reminder of the vent system was subaerial. The eruption produced >16 eruption episodes each featuring phreatomagmatic or magmatic explosive activity of sub-Plinian to Plinian intensities. The tephra fall from these explosive phases covers >20,000 km^2 and has a cumulative volume of >6 km^3 (1.3 km^3 DRE). The lava volume is 19.6 km^3. The eruption started on the South segment, ~10-15 km NE of the Katla caldera and for the first ~1.5 yrs the eruption shifted between vents just outside and beneath the glacier producing stratified phreatomagmatic tephra sequence interspersed with sporadic magmatic tephra units. This part represents the Wet Phase of the eruption. In the final 1.5 yrs the activity propagated towards the northeast, away from the Katla volcano, producing magmatic tephra (and lava) representing the Dry Phase. Eldgjá magma is rather evolved (MgO: 4.9-5.7 wt.%), mildly alkalic FeTi-basalt. Analyses of samples representing all eruption episodes show that the most primitive magma (MgO: 5.5-5.7 wt.%; Zr: 220-235 ppm) erupted during the initial Wet Phase. The erupted magma became more evolved (MgO: 4.9-5.5 wt.%; Zr: 240-280 ppm) during the Dry Phase, indicating extraction of magma from shallower levels within the crustal storage zone during the latter half of the eruption.

Theme: 3. Volcanic processes

Session 3.16: Integrating approaches to understand magma dynamics through monitoring, petrology, and modelling

Allocated presentation: Poster

Explosive Ocean Island Volcanism Explained by High Magmatic Water Content Determined Through Nominally Anhydrous Minerals

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Ocean island basalt (OIB) magmas typically contain less than 1 wt.% H_2O, making explosive eruption styles rare. When they do occur, such eruptions are thought to be driven either from volatile-enriched mantle sources or gas segregation processes during magma differentiation. In this study, we examine crystal- and water-rich porphyritic basanites and ankaramites from El Hierro in the Canary Islands, Spain, which erupted within the ≥39 ka El Golfo giant landslide collapse embayment. Combining rock and mineral chemistry with H_2O contents of nominally anhydrous minerals (olivine and clinopyroxene), we demonstrate that despite their relatively primitive composition, the post-collapse ankaramites are not primary mantle melts. Instead, they exhibit high crystal contents and unusually high water concentrations, reaching up to 3.20 ± 0.64 wt.% H_2O. These findings suggest that they represent a normally inaccessible snapshot of dense, crystal-rich magmas residing in the sub-island underplating zone. We hypothesize that their eruption was triggered by sudden decompression due to crustal unloading, implying that the El Golfo landslide may have influenced deeper parts of the magmatic plumbing system. This event likely facilitated the ascent of volatile-rich, crystal-laden magmas from the underplating zone. Based on these observations, we propose that some "wet" and explosive ocean island eruptions may result from the rise of deep-seated, water-rich magmas following vertical unloading and associated decompression.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk [Invited]

Stable open vent behaviour sustained over decades at Mt Michael, South Sandwich Islands, revealed by in situ and satellite observations

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Open vent volcanoes present unparalleled opportunities to observe volcanic processes. Mt Michael is an enigmatic mafic open vent volcano in the South Sandwich volcanic arc. Recurrent thermal hotspots in multispectral satellite imagery have motivated speculation around the existence of a persistent lava lake. We explore temporal variability in open vent behaviour at Mt Michael from the ground and from space. We combine in situ observations of gas composition, emission rate, and thermal imaging with long-term records of SO_2 and thermal emissions from satellite remote sensing to evaluate in form what magma is present at the surface and the stability of that geometry over time, determine whether gas and thermal emissions are coupled over timescales of months to years, and explain these observations in the context of the transport and storage of magma and volatiles. We measured an SO_2 flux of 135 t/d in November 2022, consistent with a concurrent satellite-based (TROPOMI) flux 120 ± 40 t/d. More energetic pulses occurred periodically every few minutes, with peaks in SO_2 flux up to 605 t/d. Deconvolving magmatic and low-temperature fumarole sources within our volcanic gas timeseries, we derive molar CO_2/SO_2 ratios of 2.1 and 5.0, respectively. Multiple vents contribute to thermal radiative power, varying between 1 and 3 in number but always in the same locations, suggesting a well-established shallow conduit geometry. We suggest that stable open vent behaviour at Mt Michael has been sustained over decades and is transitional between a classic small lava lake and a multi-vent open system volcano.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

Acoustic imaging of volcanic gas migration and degassing beneath Laacher See

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Recent findings on deep magma-related seismicity and uplift in the Eifel (western Germany) has led to a renewed interest towards monitoring volcanic degassing, especially at the Laacher See volcanic lake, formed by a series of eruptions 13 ka BP. Present-day degassing activity is evidenced by several gas seeps in the lake and surrounding shore, emitting CO_2 of magmatic origin. In this study, we used geophysical techniques during two surveys in 2019 and 2021 to image and monitor this CO_2 seepage, both in the water column and in the sedimentary infill of the lake. A multibeam echosounder was used to locate gas bubbles rising through the water column, visible by their high backscatter intensity, as well as bathymetric gas escape features on the lake floor. Additionally, high-resolution seismic reflection profiles were acquired to identify and map gas accumulations in the subsurface, evidenced by enhanced reflections and acoustic blanking. Our results show that gas is present at different depths below the lake floor, making it possible to map out areas with subsurface gas accumulations. These often coincide with areas that have a high concentration of gas seeps in the water column. Furthermore, pockmarks can be identified on the lake floor bathymetry, linking upward gas migration in the subsurface to the water column seepage. Our data confirm that CO_2 is actively migrating through the sediments and water column of Laacher See and illustrate the need for monitoring this degassing, which can contribute to a better volcanic hazard assessment in the Eifel region.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

Escalating sulphur in the Campi Flegrei fumaroles marks a step change in caldera unrest.

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The long-lived, inter-eruptive repose periods of active calderas worldwide are occasionally interrupted by phases of unrest, characterised by escalating seismicity, ground uplift, and intensifying gas emissions. The Campi Flegrei caldera, in the suburban metropolitan area of Napoli (Italy), has been restless since the 1950s, and yet the magmatic vs. hydrothermal nature of the unrest remains matter of debate. Here, we document a remarkable (factor >4) increase in H_2S concentrations in the Solfatara fumaroles of Campi Flegrei since mid-2018. Isotopic results indicate an isotopically light ($\delta^{34}S<0$ vs. Vienna Canyon Diablo Troilite, VCDT) signature for this fumarolic H_2S, consistent with the magmatic sulphur signature in the area ($\delta^{34}S$ of ~ -1.7±1.1 ‰; as inferred from the isotope composition of sulphur in silicate melt inclusions in olivines). Using results of hydrothermal gas calculations and numerical models of magmatic degassing, we propose the escalating fumarolic H_2S at Campi Flegrei to be sourced by mafic magma undergoing decompressional (ascent-driven) degassing in the 6-9 km depth range. We however cannot exclude some extent of sulphur remobilization from hydrothermal minerals due to magmatic gas-driven heating of the hydrothermal system and opening of new fractures during intense seismicity. Our results corroborate the magmatic origin of the ongoing Campi Flegrei unrest. Comparison with results elsewhere indicates escalating sulphur to be recurrent at reawakening hydrothermal volcanoes/calderas. At Campi Flegrei, any further compositional evolution of the fumaroles toward the magmatic gas range (increasing H_2S, and appearance of SO_2 and HCl) should be carefully considered as a sign of increased eruption likelihood

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

Volatiles, crustal storage depths, and degassing of alkalic, CO2-rich magmas at Nyiragongo and Nyamulagira Volcanoes, Democratic Republic of the Congo

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Nyiragongo and Nyamulagira are two of the most active volcanoes in the East African Rift System, producing some of the highest fluxes of volcanic CO_2 and SO_2 on Earth, yet pre-eruptive volatile constraints at these volcanoes remain sparse. Nyiragongo is well known for its semi-permanently active lava lake, and both volcanoes have large calderas, which formed several centuries ago (Nyiragongo) and ~300-500 years ago (Nyamulagira; Pouclet & Bram, 2021). We analyzed olivine-hosted melt inclusions (MI) from Mg-rich tephra erupted from flank cones of both volcanoes for volatile, major, and trace element compositions of MI glasses, CO_2 density in MI vapor bubbles, and Fe and S oxidation state. Lavas and tephra from Nyiragongo are highly silica-undersaturated (melilitite, nephelinite), whereas those from Nyamulagira are basanite and tephrite. Volatile solubility modeling yields magma crystallization depths of 10-16 km for primitive magmas and <5 km for evolved magmas. Although many flank vents are aligned along prominent fissures or fault systems radiating from the central edifices, our data suggest that the plumbing systems beneath the more distal flank cones are largely separated from the larger, more active magma reservoirs beneath the two edifices. Estimated CO_2 concentrations for primary melts based on equilibration with a lherzolite residue at mantle depths are very high: ~6.0 wt% for Nyiragongo and ~4.4 wt% for Nyamulagira. Degassing models based on our data show that volcanic gases released by summit activity at the two volcanoes can be explained by relatively evolved magmas feeding summit lava lakes through conduit convection and degassing.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

VOLCPLUME, an interactive open access web platform for the multiscale monitoring of volcanic emissions and their impacts on the atmosphere

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The open access VOLCPLUME web platform (https://volcplume.aeris-data.fr) is part of the Volcano Space Observatory portal under development within the framework of the Horizon Europe EOSC FAIR EASE project. This web interface aims at supporting the near-real-time monitoring of volcanic emissions and the multi-scale analysis of volcanic plumes in the atmosphere from local to global scales (Boichu and Mathurin 2022). To reach this goal, VOLCPLUME allows users to jointly analyse a broad set of satellite and ground-based active/passive remote sensing observations of both volcanic gas and particles, including Low Earth and Geostationary Orbit imagery, spaceborne and ground-based lidar, as well as photometric measurements. The platform also gives access to in-situ ground-level data from air quality monitoring networks. This synergy aims at facilitating the assessment of the multiscale impacts of volcanic plumes on atmospheric chemistry, air quality, aviation safety and climate. The « SO_2 Flux Calculator » (https://dataviz.icare.univ-lille.fr/so2-flux-calculator), a companion web application, also allows for automating the computation of daily SO_2 gas flux emissions from Sentinel-5P/TROPOMI observations with a robust noise estimation (Grandin et al. 2024). Regarding volcano monitoring and initialisation of atmospheric models, such interactive tools allow for remotely tracking changes in the degassing or eruptive activities of any isolated or non-instrumented volcano. For illustration, we present different case-studies including the eruptions of La Palma/Cumbre Vieja, Piton de La Fournaise, Soufrière Saint-Vincent and Hunga Tonga. Boichu, M. & Mathurin, T. (2022), DOI:10.25326/362; Grandin, R. et al. (2024), DOI:10.1029/2024JB029309

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

Results and reflections from a network of low-cost permanent ultraviolet cameras for sulphur dioxide measurements

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We report on the results of a growing network of ultraviolet (UV) cameras installed at seven volcanoes, based on the low-cost PiCam design from the VolcanoTech group at the University of Sheffield. The instruments are installed at: Kīlauea (USA), Cotopaxi and Reventador (Ecuador), Lascar and Lastarria (Chile), Merapi (Indonesia), and Colima (Mexico) volcanoes. Each location has a bespoke setup ranging from completely remote to integrated into existing monitoring systems with telemetry. The UV cameras provide notable advantages over other common sulphur dioxide (SO_2) emission measurement techniques, providing improvements in spatial and temporal resolution which facilitate comparison with other key data streams. Given the range of activity styles imaged, we have gained unique insights into the performance of the UV camera technique. We have grappled with common issues such as the challenges of measurements during varied emission quantities, fluctuating plume direction, and the ever-present effect of light dilution. Here, we present results across three specific activity styles at Kīlauea, showing good agreement of our results with those of traverse DOAS measurements. At Merapi, we compare our results to those from an independent NOVAC scanning spectrometer network. Finally, given optimal measurement conditions at Lastarria, we demonstrate the full capability and benefits of UV cameras. Here, we can resolve individual vents to isolate changes in outgassing through time. Overall, we suggest that installations of UV cameras for SO_2 emissions measurements offer a significant opportunity for our community to understand short and long-term gas release patterns across a range of targets.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

Tremor amplitude associated with boiling lava pond activity during the 2021 Geldingadalir eruption

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Volcanic tremor is a common signal during volcanic eruptions, but the underlying mechanisms of tremor are still not well understood. In 2021, an eruption with episodic lava effusion began in the Geldingadalir valley in Iceland. Here, we examine the tremor signal associated with episodic lava effusion on 8 June 2021, using a combination of photogrammetric data, drone video footage, and seismic tremor recordings from a seismometer near the eruption site, to investigate the timing of the tremor, eruption, and lava pond fluctuations. Our analysis reveals a distinct pattern of tremor episodes, with an average duration of 5 minutes followed by 7-minute repose. However, a closer examination of the drone video footage of one effusion episode shows that the lava pond undergoes significant fluctuations, rising and falling about 24.6 metres within 12 minutes. While the rise of the lava pond is relatively slow, taking about 10 minutes, the fall of the pond level is rapid, taking less than 2 minutes. Thus, the tremor amplitude does not correlate with the pond level, but rather peaks when the bubble bursting and spattering activity in the pond is most intense. This suggests that the tremor is closely linked to bubble bursting activity, providing insight into near-surface processes during effusive eruptions. This has important implications for understanding dynamic changes in lava ponds.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

Quantifying daily volcanic SO2 emissions on a global scale with TROPOMI and PlumeTraj

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The expression of volcanic activity at the Earth's surface is accompanied by the emission of a cocktail of different gases, including water, carbon dioxide, sulphur species and halogens. The composition and magnitude of these emissions reflects the state of magmatic systems, providing insights into volcanic processes and key hazard monitoring information. The primary target species for quantification of volcanic emissions is SO_2, due to its high prevalence in volcanic emissions, its low typical atmospheric concentration and the ability to measure it remotely from both ground and space. Satellite instruments provide a global view of volcanic activity, which is particularly useful for remote or difficult to reach volcanoes, or those without dedicated monitoring networks. In this work we combine daily SO_2 imagery from TROPOMI with the PlumeTraj trajectory analysis toolkit to detect and quantify daily eruptive and non-eruptive SO_2 emissions from volcanoes globally throughout 2020. We consistently detect more than 20 degassing volcanoes per day, dominated by persistent non-eruptive emissions. These results demonstrate the ability of TROPOMI and PlumeTraj to provide daily automatic SO_2 emissions for volcanoes globally. This will generate an invaluable dataset of volcanic degassing for investigating volcanic processes and characterising SO_2 emissions as a function of latitude and altitude, an important input for global climate modelling. In the future the presented workflow could also be applied in near real-time, providing a valuable monitoring tool.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

How may syneruptive cone collapse modify the eruption column in basaltic eruptions?

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Basaltic explosive eruptions can generate eruption columns several kilometres high, dispersing lapilli and ash across areas spanning tens of square kilometres. At frequently erupting volcanoes like Etna, in Italy, these eruptions are often accompanied by lava flows and may trigger cone instabilities that travel downslope, potentially interacting with the ash-rich column erupted from the vent. In this study, we analyse the lava fountain occurred on February 10, 2022. During this eruption, the volcanic cloud was dispersed toward the northern coast of Sicily. This event was associated with a partial cone collapse and the formation of hot, dense flows that extended few kilometres beyond the summit area. Using data from cameras, radar, and satellites, we quantify for the first time how the cone collapse influenced the dynamics of the eruption column and the associated tephra deposit. Tephra deposit was sampled at distances ranging from 1 to 23 kilometres from the vent. We estimated a total mass of 1.20 - 9.48 × 10^9 kg. The total grain-size distribution of the deposit was bimodal and the component analysis revealed a composition dominated by sideromelane. Our findings indicate that the total mass and mass eruption rate were comparable to the largest lava fountain events at Etna over the past decade. Additionally, the presence of the hot flows increased the column height by less than 2 km and slightly altered the total grain-size distribution. We believe this study gives valuable insights into the influence of cone collapse on eruption column dynamics and tephra dispersal processes.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

Enhanced Monitoring of Volcanic Emissions with the Geostationary UV Satellite Constellation

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Satellite measurements of volcanic sulfur dioxide (SO_2) and ash emissions support volcanic hazard mitigation, permit assessment of the potential climate impacts of eruptions, and provide insight into volcanic processes. Until recently, a shortcoming of ultraviolet (UV) satellite observations was low temporal resolution. However, since 2020 a new Geostationary UV Air Quality (GEO-AQ) satellite constellation has been deployed, including the South Korean Geostationary Environment Monitoring Spectrometer (GEMS) instrument, NASA's Tropospheric Emissions: Monitoring of Pollution (TEMPO), and the forthcoming ESA/Sentinel-4 mission. GEO-AQ satellites have initiated a new era of hyperspectral UV monitoring of volcanic emissions in East Asia, North America and Europe with unprecedented (hourly) temporal resolution. Prior to GEO-AQ, insight into the value of high-cadence UV satellite observations was also provided by the Earth Polychromatic Imaging Camera (EPIC), aboard the Deep Space Climate Observatory (DSCOVR) at the first Earth-Sun Lagrange point (L1) since 2015. DSCOVR/EPIC provided the first hourly UV observations of SO_2 and ash emissions from numerous volcanic eruptions, demonstrating the advantages of the increased temporal resolution now becoming available from GEO-AQ sensors. Here, we use operational SO_2 data products from DSCOVR/EPIC and GEMS and preliminary TEMPO SO_2 retrievals to highlight volcanological applications of GEO-AQ observations, including measurement of hourly variations in SO_2 emission rates, improved monitoring of multi-phase eruptions, constraints on umbrella cloud growth rates during explosive eruptions, and enhanced detection of small eruptions. Synergy between geostationary UV and infrared (IR) measurements of volcanic activity also has the potential to elucidate volcanic processes and improve satellite-based volcano monitoring.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Talk

Variability of the Villarrica volcano lava lake from the analysis of high-resolution satellite images and its relationship with instrumental parameters

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Villarrica volcano is considered the one with the highest specific risk according to the Ranking of active volcanoes in Chile and is recognized for having a lava lake in its crater almost permanently, being a key element in the population risk perception. During its last eruptive cycle (April 2022 - September 2024), the surface activity was monitored in real and quasi-real time with seven surveillance cameras, the morphological changes measured by processing satellite images Planet Scope and SkySat Collect; depth with DEMs constructed with Pleiades Stereo and TriStereo, and complemented with the analysis of thermal radiance anomalies (MODIS and VIIRS), allowing to recognize different types of variability of the lava lake in a temporal scale of days. The period of greatest manifestation of the lava lake begins in November 2023, with a sudden growth that lasts for 43 days and gradually declines until June 2024. It is characterized by the permanence of the lava lake on the surface, a maximum area of 1370 m^2 and depth fluctuations between 57 to 107 m with respect to the crater rim. This phenomenon would be triggered by magma injection at depth and subsequent re-equilibration of the magmatic column according to the relationship observed with seismic parameters, SO_2 flux and thermal radiance. Other periods, of abrupt and sporadic variability, generated the highest frequency of Strombolian activity. While the highest emissions of pyroclasts show a relationship with periods of decreased magma buoyancy.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Estimation of Volatile Degassing from Younger Deccan Traps Basaltic Volcanism across the Cretaceous-Paleogene Boundary using Geochemical, Petrological and Vesiculation Analyses

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Large-scale volcanism associated with the Deccan Traps coincided with a major extinction event at the Cretaceous-Paleogene (K-Pg) boundary, approximately 66 million years ago. Volatile emissions from these extensive basaltic lava flows likely played a pivotal role in driving climate variations during this period. In this study, the volatile budget of Deccan Traps lava flows erupting at the K-Pg boundary is measured using various geochemical and petrological techniques on the tholeiitic lava flows of the younger Wai Subgroup. Melt inclusions preserved in plagioclase and clinopyroxene phenocrysts are analysed using Electron Probe Micro Analyser (EPMA) and Nano-scale Secondary Ion Mass Spectrometry (Nano-SIMS) to provide quantitative estimates of pre-eruptive volatile content in the magma. In addition, bulk-rock trace element concentrations in the basalt, measured using wet chemistry Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), serve as proxies for particular volatile species to empirically calculate the volatile contents in the lava flows. In addition, trace volatile content in clinopyroxene grains, measured using SIMS, is used to constrain the volatile concentration of the equilibrium Deccan melt based on experimentally derived partitioning coefficient (K_D) values. Finally, the vesicle size distribution and number density plots of Deccan lava flow crusts, generated using 3D X-ray Computed Microtomography, offer insights into the syn- and post-eruptive degassing mechanisms and efficiency of the lava flows. This project aims to integrate the quantified volatile budget of lava flows with vesiculation analysis to develop a degassing model, enabling further investigation into the extent of climate modification caused by the Deccan Traps eruption.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Quantification of low-temperature gas emissions reveals CO2 flux underestimates at Soufrière Hills volcano, Montserrat

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Volcanic degassing transports volatiles from Earth's interior to the atmosphere, playing a critical role in global geochemical cycles and influencing climate on local, regional, and global scales. Volatile species not only drive volcanic eruptions but also control magma ascent processes and the style of eruptive activity. Consequently, monitoring and quantifying magmatic gas emissions and compositions are central to volcanological research. Currently, MultiGAS instruments are widely used for in-situ measurements of key volcanic gases, typically sulfur species and CO_2. However, MultiGAS instruments, which combine electrochemical and optical sensors, face challenges such as differing frequency responses and sensitivity to pressure and temperature variations. This highlights the need for improved gas-sensing technology. To address these limitations, we developed a novel optical MultiGAS (OMG) analyser capable of high-frequency, simultaneous measurements of volcanic gas species. The OMG comprises multiple optical instruments, each with an open-path multipass cell that quantifies gas concentrations at 1-4 Hz. We performed helicopter-borne OMG measurements at Soufrière Hills Volcano, Montserrat, revealing distinct spikes in SO_2 and HCl concentrations within a larger CO_2-rich plume. Acid-rich concentration spikes matched the distribution of high-temperature fumaroles, whereas CO_2 is emitted broadly from high- and low-temperature fumaroles. We demonstrate that quantification of the cold CO_2 emissions would not be possible using a standard MultiGAS instrument and that the widely used CO_2/SO_2 x SO_2 flux quantification of CO_2 flux would lead to over a threefold reduction in CO_2 flux. This suggests that traditional measurements may significantly underestimate cold CO_2 degassing, leading to underestimated global volcanic fluxes.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Foaming, shearing and outgassing in obsidians during 4D vesiculation experiments

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Vesiculation in silicic magmas controls the release of gas to the atmosphere, as well as the eruptive style of silicic volcanoes, and is often accompanied by pure or simple shear deformation. Deformation is commonly localized at the micro-scale, as revealed by the pervasive textural evidence for strain localization in explosive and effusive products. Micrometric shear bands with highly stretched and sheared vesicles can alternate with bands with more isotropic vesicles. The evolution of bubble deformation in these bands is important because: (i) deformation can reduce the percolation threshold (the transition between closed- and open-system degassing), decrease tortuosity and increase anisotropy in magma; the contribution of these processes favouring permeable gas escape; (ii) bubble deformation can be used as a strain and stress marker and hence an indicator of the stress and strain conditions extant at fragmentation; (iii) deformation can enhance rheological heterogeneities. All these consequences can influence the explosive/effusive behaviour of magma in the shallow conduit. In this study, we monitor the development and evolution of shear bands at the microscale in silicic magma using 4D synchrotron-based foaming experiments on obsidian from Lipari volcano (Italy). We measure bubble characteristics during heating-induced vesiculation, including the evolution of vesicularity, vesicle size distribution, vesicle shape and orientation, and development of permeability. Numerical simulations of pressure and velocity (linearized Navier-Stokes) and diffusive bubble growth highlight the complex feedbacks between bubble growth, pressure, shear, and outgassing. The implications for the competition between outgassing and expansion in volcanic conduits at different scales are discussed.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

First geochemical characterisation of shallow pre-eruptive magma degassing at Marapi volcano, Sumatra

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Marapi volcano, the most active in Sumatra, is characterised by recurrent short-lived explosions and occasional sustained, month-long eruptions, often preceded by limited geophysical precursors. Despite extensive monitoring efforts, our understanding of the processes and triggering mechanisms behind eruptions at Marapi remains limited, particularly due to insufficient knowledge of its gas fluxes and compositions, and how they change over time. To address this problem, we conducted several measurements of Marapi's volcanic gases, which also represent the first documented CO_2/SO_2 ratio for a Sumatran volcano and provide evidence of low sulfur content in volcanic emissions along the Sunda Arc. We used a Multicomponent Gas Analyser System (Multi-GAS) to measure the gases at the active Verbeek crater during two field campaigns between eruptions in 2014 and 2018. Both data sets reveal intermittent pulse-like degassing with a composition typical of gases from arc magma. Notably, the dataset collected just one month before the explosive eruptions on 27 April and 2 May 2018 shows a SO_2/H_2S molar ratio similar to 2014, but a CO_2/SO_2 ratio that is three times lower. This chemical shift is due to an increase in total sulfur relative to CO_2, and suggests shallower magma degassing in the weeks leading up to the two explosive eruptions. Our findings underscore the necessity for routine—and ideally permanent—gas monitoring at Marapi volcano to enhance our understanding of the magmatic processes driving its eruptions.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Gas and Trace Element Emissions at the Lava-Moss interface during the Litli-Hrutur eruption, Iceland 2023.

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During the 2023 Litli-Hrutur eruption on the Reykjanes Peninsula in Iceland, extensive lava flows resulted in the ignition and burning of vegetation surrounding the eruption site. The subsequent moss wildfires were the largest on historical record in Iceland, and generated sufficient air pollution that the eruption site was temporarily closed to members of the public. Whilst the end-member compositions of emissions from lava and vegetation burning have been studied previously, there has been limited investigation into the physicochemical processes and resulting emissions when burning occurs at the interface between them. Volcanic emissions are known to release both gases (such as H_2O, SO_2, CO_2, HCl, and HF) and trace metal and metalloid elements (including environmental contaminants Pb, As, Cu, and Cd) to the atmosphere. Where burning occurs at the interface with vegetation, however, additional elements and ligands may be available for volatilitisation from the organic plant matter. This study investigates the chemical composition of emissions from the lava-moss interface using drone and ground-based sampling approaches (filter packs, SKC Impactors, MultiGAS) as well as using automated SEM Feature analysis to apportion the source of particulate matter (PM) at different locations and altitudes downwind at the

eruption site. High resolution SEM images also reveal the physical interactions between lava and vegetation-generated particulate matter whilst in the plume. Lava-generated PM has greater potential for long range transport in the atmosphere, whilst PM derived from vegetation burning contributed to more localised and ground-based pollution. This has implications for human exposure to pollutants during active eruptions.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Thermal remote sensing of lava lakes: a physically-based algorithm

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Satellite-based thermal remote sensing is an effective tool for volcano monitoring, both for early warning and eruption monitoring. It involves detecting thermal anomalies, or hotspots, and calculating the radiative energy emitted by volcanic activity. Various volcanic hotspot detection algorithms exist in the literature. However, each algorithm has its own strengths and weaknesses, which are influenced by the tradeoffs made during its development, the type of sensor used for data acquisition, and the geometry of image acquisition. Depending on the algorithm used, different results are obtained from the same data and, hence, resulting interpretations might differ in terms of, e.g., energy emitted, effusion rates, and eruption duration. In the present work, we aim at creating a new hotspot detection algorithm that is solely based on physical laws, avoiding any empirical assumptions. We apply it to MODIS –and later on VIIRS– imagery. This new algorithm is applied to help us unravel the dynamics of thermal emissions from persistent lava lakes, i.e., bassins of lava maintained molten through thermal convection and outgassing. In the present work, we show the first results of our new algorithm on lava lake activity at Kīlauea, Hawaii, and compare them to MODVOLC and ground-based thermal camera imagery openly provided by USGS. Our initial results demonstrate a stronger correspondence with thermal camera data compared to MODVOLC. While we generally detect hotspots on the same days as MODVOLC, we also identify days of activity confirmed by the ground-based camera that MODVOLC missed, showing the greater sensitivity of our approach.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Ash-leachates chemistry as a tool for monitoring volcanic activity: An application to Stromboli volcano from 2019 to 2024

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During volcanic eruptions, the release of ash and gases triggers physical and chemical processes that result in the capture of magmatic volatiles as water-soluble minerals on ash surfaces ('ash leachates'). Previous studies have used ash leachates to examine the composition of volcanic gases and track eruption phases. Stromboli volcano in Italy, renowned for its frequent eruptions and consistent ash emissions, provides an ideal location for such research. This study investigates the temporal variation in the chemistry of leachates (Cl, F, S) from 119 ash samples collected at Stromboli between 2019 and 2024, covering various eruption conditions, including ordinary activity, paroxysms, littoral explosions and pyroclastic flows caused by lava front collapses. We focused on exploring the relationship between the chemical composition of water-soluble components on ash and the state of volcanic activity. SEM analysis of a few selected samples revealed the presence of soluble salts, like NaCl-KCl and $CaSO_4$, supporting the occurrence of gas-ash interactions within the plume. The S/Cl and S/F ratios in leachates closely match Stromboli's bulk gas signature, reflecting changes in eruptive style and plume composition, suggesting a common magmatic source. These ratios significantly increased during intense episodes, such as the paroxysms of July 2019 and 2024, which were marked by higher volatile emissions and finer ash texture, enhancing gas-ash interaction. Similar increases were observed during explosive end effusive events from 2021 to 2023, as well as 'littoral' explosions after the July 2024 paroxysm. Once these events ended, the ratios returned to typical values observed during ordinary activity.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Unravelling the mechanisms behind frequent explosive activity on El Reventador (Ecuador)

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El Reventador volcano (Ecuador) has exhibited frequent explosive activity since its 2002 paroxysmal eruption. Underpinned by data from a new permanent SO_2 camera (installed in April 2022), alongside seismic and thermal information, we investigate the Reventador's explosive activity. Average SO_2 emission rates were higher in 2022 (≈4-10 kg/s) relative to 2023 and 2024 (≈0.5-2 kg/s), whilst the number of daily explosions dips in 2023 (≈20-40 per day) with more frequent activity in both 2022 and 2024 (≈80-100 per day). Explosions originate from two distinct summit vents, although attributing a source from the camera imagery can be difficult. For a number of events we see evidence of gas accumulation caused by rapid (10-20 minutes) pre-explosive conduit sealing, whereas the majority appear to be driven by gas slugs, with no clear precursory signal. For sealing events, we identify examples of increasing gas seepage from the prior to the explosion, suggesting that the plug begins to swell and fracture shortly before explosive failure occurs. Interpretation of gas signals is often complicated by the frequency of explosions and different vent sources, with the possibility that precursory signals could be overprinted by explosion codas of earlier events or quasi-simultaneous events emanating from a different vent. Overall, the SO_2 camera installation has allowed capture of an extensive dataset in a location that is challenging for remote spectroscopic measurements, due to consistently poor meteorological conditions. Furthermore, the high temporal resolution of the system allows the capture of transient volcanic phenomena, providing insights into El Reventador's explosive activity.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

SpectroGas: the development and testing of a low-cost spectroscopic Multi-GAS

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The Multi-GAS technique is the current standard for measuring the composition of volcanic gases. However, they are prohibitively expensive, immediately restricting the measurement and understanding of gas release to financially able organisations. These instruments use non-dispersive (NDIR) spectroscopy to measure CO_2 concentrations and electrochemical sensors for other gases, such as SO_2 and H_2S. Whilst NDIR spectroscopy for CO_2 allows for precise measurements with a high temporal resolution, they typically come with a relatively high cost (£1k - £6k). In comparison, electrochemical sensors are more affordable (~£100), but due to their exposure to harsh volcanic conditions, they require frequent replacement and regular calibration. Comparisons between electrochemical and NDIR measurements are additionally challenging, due to differing response times. Therefore, new low-cost techniques which can allow for high accuracy measurements possible of capturing multiple sources need to be developed. Here, we present the development and initial testing of a new low-cost Multi-GAS instrument, called the SpectroGas, based solely on spectroscopic approaches. The SpectroGas employs broadband cavity-enhanced absorption spectroscopy (BBCEAS) which utilises optical cavities to enhance the interaction pathlength of light with the sample, the first such attempt in volcanology, for the measurement of SO_2 and H_2S. The overall instrument is lower in cost and allows for high-accuracy spatially distributed measurements at volcanoes.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Volcanic sulfur emissions from magma source to ice core archive: the case of the 1783 Laki eruption

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Large magnitude volcanic eruptions inject prodigious quantities of SO_2 into the atmosphere which can have major impacts on climate and society. While it is well established that SO_2 is oxidised to sulfate (H_2SO_4), a range of aqueous and gaseous oxidation pathways are known and there is debate as to which is dominant. Answering this question is difficult because of the challenges of sampling volcanic plumes, yet it is critical to understanding the fate and longevity of climate-impacting S species. Polar ice-cores capture high-time-resolution records of sulfate fallout from volcanic plumes and isotopic analysis of this sulfate can help determine the oxidation pathway. Despite this, no study has constrained S isotopes of erupted SO_2 and compared these values to the corresponding ice-core sulfate horizon to understand and model atmospheric processing of SO_2. Here, we examine ice-core and eruptive deposits of the 1783 Laki fissure eruption, the largest volcanic S emission of the Common Era. S isotopes of melt inclusions and matrix glass reveal characteristic degassing patterns and using mass balance we reconstruct $\delta^{34}S$ of the initial SO_2. Laki sulfate deposited in Greenland ice shows a large time evolution in $\delta^{34}S$ (from -5 to +5 ‰) and a small but detectable change in $\Delta^{33}S$ (~0.2 ‰). Using a plume box model (incorporating isotope fractionation) to compare data and models indicates a major role of the aqueous oxidation pathway catalysed by transition metals. This finding is consistent with recent photochemical models and emphasises the importance of including this pathway in volcanic emission scenarios.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Gas emissions from Mount Cleveland, Alaska, provide insights into volcanic processes

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Mount Cleveland is an andesitic stratovolcano located in the remote Aleutian Islands approximately 1,500 km west of Anchorage, Alaska, and is one of the most active volcanoes in the United States. Since 2005, activity at Mount Cleveland has been characterized by dome growth within the volcano's summit crater, intermittent explosive dome destruction events, and persistent gas and thermal emissions. The volcano is considered an open system, and explosions commonly occur without seismic precursors. In 2022 and 2023, two permanent scanning differential optical absorption spectrometers (scanning DOAS) were installed on the east side of the volcanic edifice and since then allow semi-continuous tracking of Mount Cleveland's sulfur dioxide (SO_2) emissions, even when emission rates are below those detectable from spaceborne instruments, as is commonly the case. The measurements show that SO_2 emission rates are typically in the range of 200 – 500 metric tons per day (t/d) but bursts of up to several thousand t/d occur intermittently, possibly associated with gas slugs rising from depth or small Vulcanian explosions. The spectroscopic DOAS data also show that halogen oxides, especially bromine monoxide (BrO), is present in the gas plumes at times. BrO is formed when hydrogen bromide is emitted from volcanic vents at temperatures above about 1000 K and only when gases do not significantly interact with water on their way to the atmosphere. In this contribution, we explore possible connections between gas emission rates, plume chemical speciation, and other observable volcanic processes at Mount Cleveland.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Monitoring of Ol Doinyo Lengaï volcano: new insights from photogrammetric and satellite data

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Ol Doinyo Lengaï (OL) in north Tanzania, is the only active stratovolcano in the world emitting natrocarbonatite lava and is characterized by semi-permanent activity with intermittent paroxysmal explosive events. The last paroxysm at OL occurred from September 2007 to April 2008, resulting in the formation of a 300 m wide and 130 m deep crater. This crater has since been filling up with the resumed OL's effusive activity. OL volcano is not equipped with monitoring stations and, hence, its eruptive and morphological evolution over time is not well constrained (e.g., emission rates, number of vents). Through photogrammetric analysis using crowd-source images, our recent study has shown a significant increase in OL's emission rate between 2008 and 2022, as well as several unstable features. We follow up on these observations by presenting new photogrammetric data for 2023 and 2024. These data consist of images acquired using an Unoccupied Aircraft Systems, processed to reconstruct 26 cm resolution Digital Elevation Models (DEMs). We also bring a complement of information using Sentinel-2 near-infrared satellites. These data have enabled us to estimate the radiance evolution and emission rates, and the occurrence of new collapse events at OL volcano. Our results indicate that the main lava emission area has remained stable over the past 3 years and that OL's emission rate has been decreasing since 2022, to reach 1.7×10^4 m^3/month. These cost- and time-effective techniques allow us to follow the evolution of the OL volcano and show great potential for the monitoring of all remote volcanoes.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Reconstruction of the final effusive and intrusive phase at an open vent system: the case of Lemptégy (Chaine des Puys, France)

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Lemptégy is a scoria cone in the Chaîne des Puys (France) which was formed by a complex series of Strombolian, Violent Strombolian and effusive events around 32 ka. Quarrying provides excellent exposure allowing the eruptive history of this open vent system to be reconstructed. Here we focus on the closing, effusive, phase of activity and use high-spatial resolution imaging and textural analysis to recreate the history final effusive event of Lemptégy. In addition, rheological modeling using a temperature-dependent viscosity model, plus calculated strain rates and shear stresses, reveal how void space deformation evolved under changing flow regimes. Initially lava was erupted as sheet flow at ~80 m^3/s, with flowing down the flank of the scoria cone to the north. We trace a progression from initial bubble deformation under flow-induced stress, to the formation of fractures around vesicles within brittle layers as cooling advances. As the lava solidified, down-slope creep to the east took over as the main source of stress, with well-formed shear partings developing at high mechanical stresses. In our case, this transition began after a few hours for the flow surfaces, and after a few days for the flow interior, with flow lateral creep resulting from surface up-lift due to emplacement of a cryptodome. We use the deformation characteristics of the void spaces to estimate that the cryptodome began to form ~7 hours after flow emplacement, with intrusion continuing for at-least ~30 days. This study provides insights into processes operating during shutdown of an open-vent system.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Mineralogy and formation mechanisms of the aerosol particles emitted by a permanent lava lake at Erta'Ale volcano, Danakil depression, Ethiopia.

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In a campaign 2015 aerosol and gases were sampled using in house-developed passive sampler allowing sampöing 2 – 3m above the lake, filter packs (FP), and an in-house developed Portable Gas Analyzer System (PGAS) above the lake during quiet and turbulent periods as well as from fumaroles. The chemistry, mineralogy and morphology of particles were investigated using Computer-Controlled SEM and TEM coupled with EDS. Thermodynamic equilibrium calculations (HSC Chemistry) were done to simulate the speciation of the magmatic gas mixtures and the condensation of the latter into aerosol liquids and solids. The analysis of the PGAS data and the results of the FP samples analysis show a gas composition dominated by CO_2 and SO_2, typical for open-vent volcanoes. The very quick sulfation and the preferential evoparation of potassium above the lake determines the mineralogy of the aerosol particles deposited from the emitted high temperature volcanic gas. The observed evolution of the system, well reproduced by the by HSC calculations, shows a reaction pathway going through the formation of intermediate gaseous hydrogen sulfate and oxysulfur chlorides from initial gaseous alkali chloride and hydroxide species, followed by the production of potassium rich alkali sulfate particles. The fumaroles however, release rather sodium rich sulfate particles pointing to a gas source deeper in the volcanic edifice.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Onset dynamics of paroxysmal activity from an open vent system: the Etna type case

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Paroxysmal activity at open vent volcanoes is a significant source of hazard as it occurs with limited and short term precursory activity and has a severe impact both on proximal and distal regions with tephra fallout and ash dispersion, respectively, disrupting ground and air traffic. Characterization of the eruptive dynamics can be carried out with a geophysical multidisciplinary approach comparing data from different sensors to provide fundamental details on the dynamics and the onset of these eruptions. Etna is a type case for the study of this activity as it has paroxysmal eruptions from summit craters up to several times a year, and is currently monitored by several up to date geophysical networks. This study examines geophysical data (thermal, infrasonic, radar, seismic, strain) from the INGV-OE monitoring network of nine lava fountains that occurred at Etna volcano from the South-East Crater (SEC) between February 2021 and February 2022. Based on the study of thermal signals and analyzing simultaneously the measurements of other different geophysical sensors, we identify different phases systematically preceding the climax and closing the paroxysms. Progressive multiple vent activation, increasing explosions frequency and intensity, mark the transition to the climactic phase, that generates ash-rich column of several km high and disperses tephra hundreds of km from the vent and can be interpreted as significant precursors of lava fountains. This approach is an important tool not only for understanding the Etna explosive dynamics but it can be also applicable to other volcanoes worldwide.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Comparison between UV and TIR ground-based SO2 measurements carried out at Popocatepetl volcano and validation with satellite data

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Ground-based remote sensing systems have become important tools for the monitoring of volcanic activity. They provide safe, real-time, continuous and reliable measurements with a high spatial and temporal resolution. This work presents a cross-comparison between simultaneous UV and TIR SO_2 emission rate measurements from ground-based systems carried out in a dedicated field campaign organized at Popocatépetl volcano (Mexico) in February 2024. The systems used are: (1) three high-performance dual UV imaging systems with synchronous acquisition of images and integrated spectrometer; (2) a UV MaxDoas Novac scanning spectrometer; (3) a new portable and low-cost TIR system consisting of two cameras, a broadband in the 8-14 μm window and an identical one with a narrowband filter centered at 8.7 μm in front. In particular, for this system, a correction procedure for the particles present in the plume (ash, water vapor particles, etc ...) has been developed in order to avoid their high contribution at 8.7 μm and therefore to improve the reliability of the SO_2 retrievals. Finally, the SO_2 emission rates time series obtained from the different ground based systems were cross-compared with each other and with the flux retrieved by the TROPOMI instrument on board the S5p satellite. This comparison allows to better understand the relationship between SO_2 retrievals from UV and TIR systems, their strengths and weaknesses and the problems related to the comparison with satellite data.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Retrievals of volcanic cloud properties with hyperspectral infrared satellite instruments

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Satellite data offers numerous advantages for monitoring volcanic clouds. Two of the instruments which can be used are the Infrared Atmospheric Sounding Interferometer (IASI) and the Cross-track Infrared Sounder (CrIS). They both measure in the infrared with a high spectral resolution, make measurements twice a day and have a long data record. The Earth Observation Data Group (EODG) at the University of Oxford has a number of tools for studying volcanic clouds with infrared sounders. The first rapidly detects elevated levels of SO_2 and ash. The Near Real Time SO_2 product and the outputs for 2007-2021 are displayed on a portal managed by the Centre for Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) with plans to add the CrIS and ash products. A second 'iterative' retrieval, is used to quantify information about volcanic clouds. The SO_2 retrievals have been applied to IASI spectra for the period 2007 to 2021, creating a comprehensive dataset. This dataset incorporates measurements from large explosive eruptions (e.g. Nabro and Hunga in 2011 and 2022 respectively), smaller events and ongoing degassing. It also detects a number of anthropogenic sources. We recently began a new project where we will redevelop our volcanic cloud retrievals. The new Oxford Hyperspectral Atmospheric Retrieval Package (Ox-HARP) will retrieve information about SO_2, ash, H_2SO_4 and water vapour in volcanic clouds using data from IASI and CrIS. It is also being developed with the next generation of satellite instruments, including the InfraRed Sounder (IRS) and IASI-NG, in mind.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Contrasting degassing behavior of Kanlaon and Taal volcanoes, Philippines, revealed by campaign monitoring

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Volcanic gas monitoring in the Philippines supported by current technologies for campaign and continuous measurements has yielded critical data on the currently restless Taal and Kanlaon Volcanoes. Volcanic sulfur dioxide (SO_2) measurements in Kanlaon began in 2016 through ground-based campaign surveys using a miniature-UV spectrometer (FLYSPEC). In contrast, only dissolved and diffused carbon dioxide and hydrogen sulfide were measured on Taal Volcano Island Main Crater prior to the 2020 eruption but were subsequently dominated by post-eruption SO_2 degassed in plumes and measured using FLYSPEC. Time-series data indicate that Kanlaon and Taal have exhibited different patterns in SO_2 degassing. Kanlaon emissions were mainly in the background levels except during and after discrete phreatic eruptions between 2015 and 2017. This was followed by increases leading up to the explosive eruption on 3-June-2024 and subsequent elevated SO_2 degassing with peaks of an order of magnitude greater than pre-eruption emissions. In contrast, Taal has exhibited cyclical periods of increasing-decreasing SO_2 degassing after the 2020 eruption following a year of negligible emissions. Taal further emitted the highest concentrations of SO_2 measured for a Philippine volcano. Its degassing behavior occasionally drives phreatic activity within the Main Crater Lake and produces volcanic smog that affects communities around the volcano. Time-series SO_2 data for Kanlaon and Taal have been key parameters in evaluating developing unrest and post-eruption volcanic hazards, respectively, proving critical to early-warning and preparedness. Future directions for gas monitoring are headed to continuous and real-time and multi-gas measurement stations for higher-resolution monitoring, warning and research purposes.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Insights into the 2023 eruption of Shishaldin Volcano, Alaska, from satellite SO2 emissions and complementary datasets

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Shishaldin Volcano, Alaska, is a remote and frequently active basaltic stratovolcano that exhibits a range of eruption styles. Shishaldin's most recent eruptive period occurred between July and November 2023 and consisted of 13 explosive events with ash clouds reaching up to ~14 km altitudes. Given Shishaldin's remote location, TROPOMI satellite-derived SO_2 emission measurements were a key parameter used by the Alaska Volcano Observatory to track volcanic activity during this eruption. Throughout most of the eruptive sequence, SO_2 emissions were primarily associated with large explosions. However, during a 2-week period in October, SO_2 plumes were detected daily in the absence of significant explosive activity as determined through seismic, infrasound and webcam observations. Based on gas compositions measured during a 2015 field campaign, and a Shishaldin-specific degassing model, we infer that substantial sulfur does not exsolve from Shishaldin's basaltic magma until depths of <3 km. This suggests that satellite SO_2 observations can be used to track shallow magma ascent and degassing at Shishaldin. We use the cumulative SO_2 mass emitted during the 2023 eruption (0.32 Mt) along with the melt S concentrations from the 1999 eruption (ΔS ~1500 ppm) to estimate a total dense rock equivalent volume of degassed magma of ~50 x $10^6 m^3$. Comparing this result with the 2023 deflation volume (~10 x 10^6 m^3), we estimate a ratio of eruptive to intrusive (degassed) magma of ~0.2. This case study highlights the utility of satellite SO_2 data when combined with complementary datasets to inform eruptive processes, especially at remote volcanoes.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Diffuse CO2 degassing and its origin in the Tatun Volcano Group, Northern Taiwan

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The Tatun Volcano Group (TVG), located in northern Taiwan, is an area of significant volcanic and geothermal activity. This study systematically investigates the spatial distribution and sources of diffuse carbon dioxide (CO_2) emissions to quantify degassing processes and evaluate their correlation with volcanic activity. A total of 448 soil gas flux measurements, conducted over a 10 km^2 area using the closed-chamber method, revealed substantial CO_2 emissions from both hydrothermal and non-hydrothermal zones. The identification of well-developed fractures and degassing structures in non-hydrothermal areas highlights their role in facilitating deep-seated gas migration to the surface. Isotopic analyses of carbon and helium confirmed the mantle-derived origin of the emitted CO_2, indicating contributions from magmatic and crustal sources. High-CO_2 flux zones interacting with shallow hydrothermal systems were linked to carbonate precipitation and altered isotopic signatures, suggesting the presence of shallow aquifers. Temporal analysis of soil CO_2 flux in the Dayoukeng (DYK) hydrothermal area from 2009 to 2024 showed a 210% expansion of degassing zones, correlating with elevated soil temperatures and water vapor anomalies. These findings emphasize the need for continuous monitoring to assess volcanic hazards, particularly in high-risk non-hydrothermal areas, and contribute valuable insights into TVG's degassing mechanisms and underlying magmatic processes.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

The influence of plumbing architecture on magma dynamics and volcano monitoring: a contribution from the multidisciplinary petrological and geochemical framework (PGF)

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Forecasting changes in volcano activity requires a detailed understanding of magma plumbing architecture and dynamics in terms of geometry, distribution and connectivity of the magma bodies and magma properties. The PGF's multidisciplinary approach, we have adopted over years combines the petrological study of erupted products with the geochemical monitoring of gas emissions. This framework permits to constrain magma evolution and dynamics within a plumbing system over a very large range of pressure, temperature and compositions, time scales and frequencies of eruptive events. Here we review the most recent results obtained on two active volcanic systems (Piton de la Fournaise and Mayotte), formed in distinct geodynamic settings and with very contrasting eruption rates, volumes, and dynamics, but sharing a common feature: an important lateral shift of the deep plumbing with respect to the eruptive sites and the coexistence of both evolved (phonolite to trachyte) and mafic (basalts to basanite) melts over a large depth range. We show that the most effective monitoring is obtained by focusing on the deepest parts of the plumbing system that allow recognizing new magma recharges and lateral drainage. The occurrence already in the mantle and close to the Moho of variably evolved and degassed melts, besides primitive and volatile rich ones need to be carefully considered, in order to provide a robust interpretation of petrological and geochemical datasets. In this frame, the continuous flushing of the whole plumbing system by CO_2-rich fluids plays a major role on melt evolution, storage, transfer and ultimately eruption.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Volcano monitoring of El Hierro island (Canary Islands, Spain) through diffuse CO2 degassing surveys

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El Hierro (278 Km^2), the youngest and westernmost island of the Canary archipelago, sits on an ocean floor 3.5 km deep and rises 1.5 km above sea level. Formed ~1.12 million years ago through rapid constructive and destructive volcanic processes, the island experienced a submarine eruption 2 km off the southern part of the island from October 2011 to March 2012, being the first volcanic eruption fully monitored from its onset in the Canary Islands. Diffuse degassing studies have been an important volcano monitoring tool at El Hierro, since there are no current visible volcanic gas emissions on the surface. Annual surveys of diffuse CO_2 emissions began in 1998 and were intensified during the 2011–2012 unrest. Each survey involves 600 sampling sites where soil CO_2 efflux is measured using the accumulation chamber method, and soil gas samples are collected at 40 cm depth for chemical and isotopic analysis of CO_2. During the preeruptive and eruptive periods, the diffuse CO2 emission released by the whole island experienced two significant increases: 2 weeks before the onset of the submarine eruption and several days before an increment in the amplitude of the tremor signal. In the latest survey (summer 2024), CO_2 values ranged from non-detectable to 44 $g \cdot m^{-2} \cdot d^{-1}$. the diffuse CO_2 emission was estimated in 699 ± 32 $t \cdot d^{-1}$, slightly higher than the background average of 410 $t \cdot d^{-1}$. These findings highlight the importance of discrete CO_2 monitoring for enhancing early warning systems in volcanic surveillance programs.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Insights into eruption dynamics from TROPOMI/PlumeTraj-derived SO2 emissions during the 2022 eruption of Mauna Loa, Hawai'i

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Volcanic fissure eruptions can produce voluminous gas emissions, posing a risk to local and distal populations and potentially impacting global climate. Quantifying the emission rate and altitude of injection of these emissions allows forecasting of impacts and provides key insights into the magma dynamics driving eruptions. Daily global observations from satellite instruments such as TROPOMI combined with trajectory modelling with PlumeTraj delivers these emission rate and altitude data. Here, we report satellite-derived SO_2 emissions from the 2022 eruption of Mauna Loa, which lasted only 13 days but produced an SO_2 plume that circled the globe, displaying a highly variable emission rate and injection altitude. Three key discoveries were made: we detect precursory SO_2 emissions up to three hours before the eruption start; peaks in emission rate are correlated with onset and cessation of activity at different fissures; the SO_2 injection altitude was modulated by the moisture content of entrained ambient air. We suggest that alignment of the fissure geometry with the wind direction could potentially explain how the initial emissions reached 14 km asl, approaching the tropopause. The total SO_2 measured from this eruption is 600 (± 300) kt. These results demonstrate how satellite measurements can provide new insights into eruptive and degassing mechanisms and highlight that better constraints on the SO_2 emissions from fissure eruptions globally are needed to understand their impact on climate.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Diffuse CO2 degassing and thermal energy release from Teide volcano summit crater, Canary Islands

Eleazar Padrón*[1,2], Nemesio M. Pérez[1,2], Gladys V. Melián[1,2], Pedro A. Hernández[1,2], Luca D'Auria[1,2], María Asensio-Ramos[1], Germán D. Padilla[1,2]

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Diffuse soil CO_2 efflux studies have shown that the amounts of CO_2 released by non-visible degassing can be similar or even much larger than CO_2 released through advection from fumaroles and volcanic plumes. As most quiescent volcanoes dissipate important amounts of energy through the direct expulsion of volcanic-hydrothermal fluids, the estimation of the flux of thermal energy associated with diffuse degassing is relevant for both volcanic surveillance and geothermal exploration. The summit cone of Teide volcano (Tenerife, Canary Islands) shows a weak fumarolic system and high rates of diffuse CO_2 degassing, that represent the main degassing mechanism. Both fumarolic discharges and diffuse CO_2 degassing rates have been monitored regularly since 1999 at the summit crater of Teide volcano. The computation of the thermal energy release based on the diffuse CO_2 degassing rates has been done by calculating thermal energy given off by the associated steam condensation. The time series of both thermal energy and seismic energy release shows an important increase after 2016, undoubtedly related to the occurrence of an input of magmatic fluids triggered by an injection of fresh magma and convective mixing, with a subsequent significant increase in seismic activity recorded in and around Tenerife Island. The accumulated thermal energy released from the summit crater of Teide associated with the diffuse degassing of hydrothermal fluids in the period 1999-2024, has been estimated in 1.9×10^{10} MJ, two orders of magnitude larger than the seismic energy released in and around Tenerife Island in the same period, estimated in 4.8×10^{8} MJ.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Diffuse CO2 emission from NERZ, NSRZ and NWRZ Tenerife volcanic systems, Canary Islands

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Tenerife (2,034 km^2), the largest of the Canary Archipelago, features three volcanic rift zones-oriented NW-SE, NE-SW, and N-S, with a central volcanic structure, Las Cañadas caldera housing Teide-Pico Viejo volcanic complex. Since 2000, yearly CO_2 degassing surveys have been conducted along the NW (72 km^2), NS (325 km^2), and NE (210 km^2) Rift Zones (RZ) as part of the volcano geochemical monitoring program. Soil CO_2 efflux measurements have been always performed by means of the accumulation chamber method. To construct contour maps and estimate total CO_2 emissions, Sequential Gaussian simulation (sGs) interpolation has been used. Results of soil CO2 efflux measured during 2024 surveys showed values from non-detectable to 39.9$g·m^{-2}·d^{-1}$, with mean values of 3.1, 2.2, and 1.3 $g·m^{-2}·d^{-1}$ for NERZ, NWRZ, and NSRZ, respectively. Estimated diffuse CO_2 emissions were 508±15$t·d^{-1}$ (NWRZ), 279±11$t·d^{-1}$ (NSRZ), and 128±9$t·d^{-1}$ (NERZ), corresponding to normalized rates by studied area of 2.4, 0.9, and 1.8$t·d^{-1}·km^{-2}$, respectively. Temporal evolution of time series of the three RZ show a continuous increase from 2013 to 2021, prior to the volcano-tectonic seismic swarm of April 2015 and the increase in seismicity recorded from the end of 2016, with the occurrence during this period of several LP-type seismic swarms (Hernández et al., 2017), to subsequently show an opposite downward trend. Our data suggest that temporal variations in CO_2 emissions are linked to seismic activity, reflecting dynamic processes within Tenerife's hydrothermal-magmatic system. Hernández et al. (2017). Bull. Volcanol., 79:30, doi: 10.1007/s00445-017-1109-9.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Intercomparison of remote sensing methods for field measurements of volcanic gas emissions

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Significant progress has been made, especially in the last 20 years, in the development of portable methods for remote sensing of volcanic gas emissions in the field. These tools help volcanologists to obtain, often in real-time, important information about the level and impact of volcanic activity, including plume composition, flux, location or speed. Some instruments measure the same variable but with different sensitivities, spatial or temporal resolution, while others may provide complementary information. Intercomparison between different methods is essential to ensure reproducibility of measurement results and to improve protocols and strategies for using complementary techniques. We present

the results of an intercomparison exercise conducted at Sabancaya Volcano (Peru) on 10-11 November 2022, during the 14th Field Workshop of the IAVCEI Commission on the Chemistry of Volcanic Gases (CCVG). Measurements were taken by 12 groups with a variety of passive remote sensing techniques, using scattered light, solar occultation and thermal emission. Spectrometric and imaging equipment used non-dispersive, dispersive and interferometric techniques from the ultraviolet to thermal infrared regions. The results of independent evaluations reveal SO_2 fluxes between 22 and 45 kg/s, molar ratios of 10-22 for SO_2/HCl and of 34-53 for SO_2/HF 34-53. Results from coincident measurements using the same technique show relatively good agreement, while some discrepancies are observed between the results of different techniques. Possible causes of disagreement will be analysed, including natural variability for non-coincident measurements, varying choices of calculation parameters, different spectral evaluation settings, or physical effects caused by light extinction from air or ash.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

A collaborative effort towards improving volcanic gas monitoring and eruption forecasting in Colombia: the case studies of Nevado del Ruiz, Purace, and Galeras

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Since 2017, the University of Palermo and the Geological Survey of Colombia have collaborated to enhance the role of volcanic gas monitoring in forecasting eruptions and mitigating volcanic hazards in Colombia. This ongoing partnership focuses on the Nevado del Ruiz, Purace, and Galeras volcanoes. Here, we summarize results gathered over approximately seven years (2017–present) and highlight significant shifts in volcanic activity during this period, such as the Nevado del Ruiz crisis (July 2021-October 2022 and March-June 2023) and the Purace crisis (May-July 2024). We present data from permanent multi-sensor gas monitoring stations installed at Nevado del Ruiz, along with gas composition surveys conducted at Galeras and Purace. Additionally, we introduce new data from a semi-permanent ultraviolet (UV) camera installed at Nevado del Ruiz and explore the potential for integrating both UV camera and Novac network data to obtain more accurate estimates of daily SO_2 fluxes. This integration is particularly crucial at high altitudes, where seasonal wind patterns (e.g., direction and speed) can introduce significant errors in SO_2 flux estimates. Furthermore, the implementation of novel acquisition and automated data processing techniques from our permanent gas stations facilitates the development of volcanic gas monitoring protocols suitable for contexts with real-time data transmission capabilities. Ultimately, our volcanic gas data are combined with ongoing petrological investigations of these volcanic systems, particularly Nevado del Ruiz, to assess their current state of unrest and the likelihood of future eruptions.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

CO2 flux from Ribeira Quente river (Furnas Volcano – São Miguel, Azores)

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Ribeira Quente river drains out Furnas Volcano, an active quaternary central volcano located in the island of São Miguel (Azores), being influenced by hydrothermal discharges. To characterize CO_2 diffuse flux, measurements were made following the accumulation chamber method. Measurements were made systematically along the major river and the most important tributaries in the Ribeira Quente watershed along two surveys, totalizing 210 points and 215 points, respectively. Flux measurements are in the range between 0.4 and 24,085.5 g.m^{-2}.d^{-1} (mean = 518.5 ± 1,901.8 g.m^{-2}.d^{-1}; median = 25.5 g.m^{-2}.d^{-1}), and between 2.2 and 10,637 g.m^{-2}.d^{-1} (mean = 334 ± 884.9 g.m^{-2}.d^{-1}; median = 46.1 g.m^{-2}.d^{-1}), respectively along surveys 1 and 2. The background values of biogenic origin were estimated as 20 to 31 g.m^{-2}.d^{-1}. Flux along the several paths along which measurements were performed show sharp increases relative to background values whenever hydrothermal discharges to the river take place. Through the integration of the mean values, diffuse CO_2 emission was calculated as 20. 5 t.d^{-1} and 23.8 t.d^{-1}, respectively for surveys 1 and 2. This approach considers continuity along the overall area where measurements took place, and seems that overestimates the area, thus leading to a higher overall flux compared to the ones calculated by dividing the river channel in several sections and computing separately each contribution (15.5 t.d^{-1} and 13.0 t.d^{-1}). The overall CO2 flux in the watershed is estimated as 17.8 t.d^{-1} and 14.6 t.d^{-1}, considering the contribution of all tributaries where values are of biogenic source.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Temporal variations in fumarole gas chemistry at Teide volcano, Tenerife, Canary Islands

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As part of the geochemical monitoring of Teide volcano, the only active stratovolcano in Tenerife (Canary Islands), during the last three decades the volcano has been the subject of a geochemical monitoring of the fumarole discharges, characterized by low flux emission of fluids with temperatures of ~83°C, located at the Teide summit crater. The temporal variations in fumarole gas chemistry at Teide volcano was useful to detect significant changes in the chemical composition of the Teide fumarole one year before a seismic crisis that occurred in Tenerife Island between April and June 2004, suggesting that associated temporal changes in seismic activity and magmatic degassing indicate that geophysical and fluid geochemistry signals in this system are unequivocally related. The average of the air-corrected 3He/4He ratio during the period 1991-2024 was 7.03 RA (being RA the atmospheric ratio), with the maximum value of the time series (7.57 RA) measured in August 2016, when an input of magmatic fluids triggered by an injection of fresh magma and convective mixing took place beneath Teide volcano. After 2016, the observed changes in the fumarole gas chemistry of Teide volcano suggest a certain disequilibrium in the volcano-hydrothermal system of Teide due to sustained heat pulses, likely caused by the input of magmatic fluids. This work highlights the important role of volcanic gases in the monitoring of volcanic activity, paying attention to different chemical and isotopic species in the fumarolic discharges.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Helium, carbon and nitrogen isotope evidence for slab influence on volcanic gas emissions at Rabaul caldera, Papua New Guinea

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The chemical and isotopic composition of arc volcano gases offers insights into the origin of magmatic volatiles. In volcanic arcs, magmatic volatiles can be supplied from the mantle, the subducting slab, or the rocks of the arc crust. Determining the relative contributions of these distinct sources is important for understanding the transfer of volatiles between Earth's interior and exterior reservoirs, which has implications for the physical and chemical evolution of the mantle and the atmosphere. Each subduction zone has a different recycling efficiency, controlled by the composition of the slab and the pressure-temperature path it experiences upon subduction. Thus, all volcanic arc emissions can be characterised by their chemical and isotopic compositions. In this study, we analyse the composition of volcanic gases from Rabaul caldera in the New Britain subduction zone, Papua New Guinea, and show that the emissions are substantially influenced by slab recycling of carbon and nitrogen. We find helium emissions are dominated by a mantle contribution, with little crustal influence. Carbon isotopes point towards a mixture of mantle, carbonate and organic sediment-derived contributions, with the dominant input coming from carbonates. This may be of sedimentary origin, seafloor calcareous muds, or altered basalts of the subducting oceanic crust. Nitrogen isotopes also indicate a significant influence of sedimentary nitrogen. Our study is the first comprehensive investigation of volatile sources in the New Britain subduction zone and our results and interpretation are consistent with previous studies of element recycling based on New Britain arc lavas.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Assessing impact and dynamics of cone collapses triggered by explosive eruptions: the February 10 2022 eruption of Mt Etna (Italy)

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Cinder cones of persistently active volcanoes are unstable, rapidly growing edifices that change in shape and volume due to eruptive events, vent shifting and collapses. They are subjected to repeated building /destruction phases. Triggering mechanisms of cone collapses can be very variable as they can occur in between or during eruptions. Understanding their dynamics and onset mechanisms requires collecting a multidisciplinary dataset, based on both remote sensing and field studies. We present a model for the onset and flow dynamics of multiple syn eruptive collapses occurred during lava fountain at Etna volcano (Italy) on February 10 2022. We collected data from visual and thermal monitoring, UAS and satellite based data and field surveys. While the effect of the eruption dynamics on cone instability and the volume of the collapsed mass could be assessed based on remote sensing data, the dynamics of transport and depositional mechanisms of the flows could be modeled based on stratigraphic and sedimentological studies of the deposit. Our results suggest that dyke intrusion and multiple vent opening were key processes in triggering collapses, and that the internal cone structure controlled the volume and dynamics of the flows. This also confirm that the impact of these events could be significant, especially in areas of mass tourism, and that they should be considered for hazard assessment in proximal areas of persistently active volcanoes.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Experimental vesiculation and shearing in conduits of increasing size

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Transport in cylindrical conduits is thought to be a common pathway for magma ascent in the near surface. Field observations of lava domes and volcanic vents suggest shearing at the conduit margins promotes localized degassing during ascent and eruption. Despite their ubiquity in interpretations of field observations and the setup of numerical models, experiments that allow for vesiculation and flow of natural materials in open-topped cylindrical geometries remain sparse. We present high-temperature vesiculation experiments of natural obsidians that flow in cylindrical crucibles as a result of their own volume expansion during heating-induced vesiculation. Shear can occur either late in vesiculation, when the sample already contains abundant vesicles, or synchronous with bubble growth. Measurements of permeability on solidified samples show that shear promotes bubble connectivity. But what happens at larger scales when only the margins of the transporting magmas are sheared? We progressively increase the size of samples from 5 mm to 180 mm in diameter to demonstrate the localized effects of shearing and understand the connection between sample interior and margins. Experiments are then used to calibrate numerical models of bubble growth in the sample geometry which improves our ability to predict the dynamics of meter-scale volcanic conduits.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Investigating Noble Gas Outgassing Dynamics in MORB and OIB Magmas with a New Lattice Boltzmann Method

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Noble gas fractionation during magma ascent is governed by ascent rates, volatile concentrations, and the dynamics of bubble growth and nucleation. When degassing occurs rapidly relative to diffusion, kinetic fractionation effects can arise. Because heavier noble gases diffuse more slowly than lighter noble gases, they are more sensitive to these effects, creating noble gas ratios in melts (e.g., 4He*/40Ar*) that differ from those generated by solubility-controlled equilibrium degassing. However, bubble nucleation during ascent can counteract kinetic fractionation by reducing diffusional length scales. The extent of kinetic fractionation recorded in MORB and OIB magmas remains poorly constrained, but an increased understanding of this process could improve estimates of volatile fluxes from the mantle to the atmosphere (Tucker, 2018). To address this, we developed a Lattice Boltzmann model of bubble growth that incorporates noble gas diffusion, bubble dynamics, and nucleation events. This method is based on statistical mechanics, where continuum equations (e.g., Navier–Stokes, diffusion) are represented by the advection and collision of particle distribution functions. We compare our simulation results to MORB and OIB noble gas concentrations to determine the relative influence of kinetic and equilibrium degassing processes on these melts. This will help constrain undegassed volatile contents within their parent magmas and improve estimates of volatile fluxes to the atmosphere, which are an important control on long-term climate. Additionally, by providing noble gas concentrations in individual bubbles across their size and growth history, we provide a framework for interpreting individual bubble composition analyses (Colin et al., 2015).

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Estimating lava lake and exposed magma conduit levels using satellite-derived volcanic radiative power.

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Open-vent volcanoes represent a direct connection from magma storage regions to the surface and provide excellent opportunities for scientists and geo-tourists to observe volcanic processes. However, the often benign activity can shift to eruptive behaviour, sometimes rapidly and unexpectedly, and this transition is difficult to forecast even at well-monitored systems. At volcanoes hosting lava lakes, the lake level has been linked to system pressure, with high pressure being related to higher eruptive potential. Monitoring lava lakes and exposed magma columns therefore provides helpful information for eruption forecasting. However, at systems where ground-based monitoring is precluded alternative approaches are needed. Here, a new simple method using volcanic radiative power (VRP) to estimate the height of lava lakes and exposed magma columns is presented. VRP is a measure of the energy emitted by volcanoes, typically calculated from satellite-retrieved middle infrared measurements. VRP varies depending on the temperature and radiating surface of a lava body, and so by assuming one variable the other can be calculated. By assuming a simple flaring cone geometry, the estimated radiating area allows the calculation of an approximate level of a lava body within a crater. Preliminary results from Manam volcano, Papua New Guinea during the 2018–2021 elevated eruptive period shows the magma column frequently rising into Manam's South Crater. An estimated intra-crater magma level of 1 metre on 17/05/2019 agrees with the only visual observation of South Crater on 20/05/2019[AC1] . Future development includes extensive ground truthing, and development with real geometry and non-flaring cone geometries.

Theme: 3. Volcanic processes

Session 3.17: Volcanic Degassing and Open Vent Volcanoes

Allocated presentation: Poster

Syneruptive and diffuse degassing of mercury at Piton de la Fournaise volcano (Reunion Island)

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Volcanoes are the primary natural source of mercury in the atmosphere. However, these emissions remain poorly understood, particularly in intraplate settings. Available data from volcanic vents during eruptions indicate low mercury emissions compared to arc volcanoes. Intraplate volcanoes, however, tend to release most of their gases through continuous diffusion from magma stored at significant depths, as opposed to during eruptive events. This is well-documented for carbon dioxide, but whether the same holds true for mercury remains unknown. In this study, we use the Piton de la Fournaise volcano (Réunion Island) as a natural laboratory to investigate volcanic degassing of mercury, both diffuse and syneruptive. Previous research has detected magmatic CO_2 in soil gases, groundwaters, and surface waters along a rift zone, attributing this degassing to magma reservoirs located at different depths (10 km and 30 km) or to plume deposits. We measured the concentration and isotopic composition of mercury in these same gases and waters, as well as in soils and in the atmosphere. Our results show low mercury concentrations in all samples, with isotopic signatures in soil gases suggesting a magmatic contribution from diffuse degassing from the deepest magma reservoir.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Talk

Lithium in volcano-sedimentary deposits: an overview

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The increase of the lithium (Li) demand, driven by its importance to develop low-CO_2 emission technologies, makes the discovery of new esources and of new deposit types pivotal to securing a sufficient future supply of this critical commodity. Volcano-sedimentary (VS) deposits represent a relatively poorly studied and still underdeveloped type of Li resource. These deposits consist of mixed volcanic-sedimentary successions deposited in closed basins developed in felsic magmatic provinces. The Li ore in VS systems includes complex mineralogical assemblages dominated by phyllosilicates and borosilicates formed from the alteration of Li-fertile felsic volcaniclastic/pyroclastic suites. In this contribution we present an overview of the geological features of VS Li deposits with the goal of providing a generalized and updated deposit model. We focus on several key characteristics of VS deposits, including: 1) the relationship between specific tecto-magmatic environments and the generation of Li-rich melts; 2) the mechanisms of transfer of Li from the igneous to the volcano-sedimentary environment; 3) the main alteration mechanisms linked to the Li upgrade in the critical zone and the formation of secondary ore-bearing assemblages. These aspects are discussed based on published available data, but also by presenting new observations on representative VS deposits from western US, eastern Europe and elsewhere.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Talk

Contrasting Timescales of Volatile Degassing from Hydrous Magmas in Porphyry Copper Systems

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The timing and duration of volatile generation from crystallizing magmas and fluid release across the magmatic-hydrothermal interface are complex processes governed by non-linear, dynamic interactions between magmas, rocks, and fluids. The interplay of these processes can lead to the formation of ore deposits or trigger volcanic eruptions. To investigate and quantify these mechanisms, we developed a novel coupled model for magmatic-hydrothermal systems with a consistent formulation for fluid generation and transport with viscous magma flow and porous fluid flow. Our simulations use an up-scaled description of volatile release from reservoir to host rock and realistic magma properties from published experimental and modelling works. The results suggest that the cooling of hydrous magmas can involve distinct phases of volatile release, each with its unique timescale and implications for magmatic and hydrothermal processes during the development of porphyry copper systems. Magma convection with bubble suspension in melt-dominated states leads to homogenization, delaying fluid release and promoting a rapid evolution towards a mush state. The onset of volatile release can be near-explosive, with tube-flow outburst events lasting less than 100 years for high initial water contents, potentially forming hydrothermal breccias and vein stockworks or triggering eruptions. This initial event can be followed by sustained fluid release at moderate rates due to volatile flushing caused by magma convection. Subsequent continuous fluid release from concentric tube rings by radial cooling of non-convecting magma mush lasts <100 kyr. Our simulation results show how voluminous water-rich upper-crustal magma reservoirs can form large porphyry deposits.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Talk

Key new insights into controls on magmatic ore fertility through melt inclusions at the Parinacota volcano

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The redox state of magmas significantly affects their physical properties, differentiation , ore-forming potential, and the emission of sulfur-bearing gases into the atmosphere. Oxidized, sulfur-rich magmas are prevalent in convergent plate margins and are responsible for forming large porphyry Cu-(Mo-Au) deposits, the primary sources of copper and molybdenum for modern society. This study investigates the origin of these key characteristics through the analysis of silicate melt inclusions, hosted in olivine and clinopyroxene, in volcanic rocks from the Parinacota volcano, located in the Central Andes. The findings reveal oxidized, near-primitive mantle melts that exhibit co-enrichment in sulfur, strontium, barium, thorium, and light rare earth elements. Importantly, no evidence was found to suggest further oxidation during magma differentiation. These results suggest that the oxidized state of arc magmas is predominantly attributed to the flux of sulfate-rich sediment melts derived from the subducting slab. This process enriches the magmas not only in sulfur but also in strontium and light rate earth elements. This mechanism may be integral to explaining the elevated Sr/Y and La/Yb ratios commonly associated with magmas that generate porphyry-type ore deposits. These insights provide a clearer understanding of the processes driving the redox evolution and metallogenic potential of arc magmatic systems.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Talk

A potential reserve of critical raw materials in the Sabatini geothermal field, Italy

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The Pleistocene (~800-70 ka) Sabatini Volcanic Complex hosts a geothermal field that has recently been the focus of renewed research interest to explore potential lithium resources in hydrothermal brines in Italy. However, the metasomatic calcsilicate (skarn) rocks hosting such brines may also have economic importance, potentially hosting critical raw materials. Using borehole core and cutting samples (ENEL-SH2 well; depth= 2498 m), we defined the mineral assemblage of the skarn rocks and the in-depth distribution of the REE-bearing minerals (vesuvianite, garnet, titanite) to estimate the potential reserve, integrating microtextural investigations with XRD, EMPA and LA-ICPMS techniques. Boron-rich vesuvianite (wiluite) is the most abundant mineral within the depth interval of -1400 to -1650 m, with an average modal content of 22 vol%. Vesuvianite exhibits an average B content of ~7500 ppm, high total REE oxides (TREO) content, and an average U content of 113 ppm. Using the available geological reconstruction from drilling and residual gravity modeling, we estimate a total (minimum) volume of the vesuvianite skarn of ~0.5 km^3. These preliminary results suggest the economic importance of the hydrothermal mineralization associated with the Sabatini geothermal field as a potential REE reserve and strategic repository for critical raw materials in Italy.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Talk

Rapid ascent of volatile-charged magma associated with porphyry Cu deposits: Models and crystal textures

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Porphyry copper deposits (PCDs) are associated with felsic hypabyssal intrusions with geochemical signatures indicating a water-rich source in the mid- to lower-crust. Such wet felsic magma would be very buoyant, and we explore the hypothesis that its rapid ascent through the crust via dikes promotes PCD generation. A mathematical model for dike ascent with vesiculation (H_2O and CO_2), heat transfer, crystallization (including kinetics and evolving crystal size distribution) and latent heat release, demonstrates that extremely fast ascent of volatile-charged magma from PCD-relevant source conditions is feasible. For example, a water-rich dacite can ascend from 30 to a few km depth in days. This is sufficiently fast to prevent substantial loss of exsolved volatiles (and metals) to surrounding rocks during ascent. However, to form a PCD the volatile-charge magma must not accelerate to the surface and erupt explosively like a kimberlite. The modelling shows that there are conditions for which wet felsic magma that ascended rapidly can decelerate to form an intrusion in the upper crust due to viscosity increase from substantial crystallization induced by water exsolution and cooling. Dike ascent is faster, with more shallow arrest, for wetter, hotter magma and for greater amount of magma entering the dike. We compare simulated crystal textures with those of natural volcanic and intrusive rocks, and products of experiments replicating magma decompression paths from model runs. We combine the numerical modelling and textural results with conceptual models of sources and deposits to discuss conditions that may be more conducive to PCDs than eruptions or barren intrusions.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Talk

Magma recharge processes in continental flood basalt reservoirs: Evidence from the 1.27 Ga Coppermine River Group, Nunavut, Canada

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Large igneous provinces (LIPs) are high volume magmatic events that consist of flood basalts, gabbroic sills and dykes, and layered intrusions. LIPs are important targets for critical metals (e.g., Cu, Ni, Co, PGEs) hosted in mafic intrusions. The 1.27 Ga Mackenzie LIP of northern Canada includes flood basalts and feeder dykes of the Coppermine River Group (CRG), the Muskox layered intrusion, and the Mackenzie dyke swarm. Knowledge about the Ni-Cu-PGE prospectivity of the Mackenzie LIP is based on previous studies of the open-system Muskox intrusion and feeder dyke. In contrast, the mineral prospectivity of CRG flood basalts and feeder dykes is unknown. We present the preliminary results of a collaborative, multiscale investigation of the CRG aimed at (1) establishing the spatial distribution and interconnectivity of magma reservoirs as a key factor in developing structural traps hosting ore deposits, and (2) detailed mapping of the feeder system to resolve compositional links between the CRG and the Muskox intrusion. We report the results of a mineralogical study to characterize the crystal cargo(es) and textures of lava flows in the lowermost part of the CRG. Studies of lava-hosted mineral textures inform on host magma evolution and enable putative links to Muskox cumulates to be tested. Compositional zoning of silicate phases provides a snapshot of magmatic compositions for different stages in the evolution of the CRG volcanic system, including replenishment by Mg-rich magmas from deeper reservoirs. Such data have the potential to elucidate metallogenic processes associated with Ni-Cu ore genesis in the CRG.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Talk

Volcanoes as windows into metal processing pathways in the crust

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Crustal enrichments in chalcophile metals and metalloids such as copper, selenium and gold are of interest because of increasing global demand for these elements related to the energy transition. These elements are, under certain conditions, enriched in porphyry magmatic systems located in subduction zone settings. Understanding pathways of metal enrichment through silicate melts, sulfide and exsolved volatile phases is key to understanding how these enriched porphyry systems form. Volcanoes provide us with a means of examining and understanding these pathways through study of exsolved fluids (gases and aerosols), textures of erupted rocks, as well as melt inclusions and whole rock element abundances. The abundance of Cu (and other sulfide-loving elements) in silicate melts, for example, is strongly influenced by sulfide saturation and volatile degassing during fractionation. Here I present a range of datasets from volcanoes in different settings and use them to generate generic models to quantify the impact of magmatic water content on Cu pathways during crustal evolution of arc magmas and the implications for the abundance and distribution of sulfur and Cu in saline magmatic fluids. Ubiquitous sulfide saturation is a critical limitation on the chalcophile element and sulfur load of exsolved magmatic fluids. However, reactive flow through mush zones involving sulfide-undersaturated melts may resorb accumulated sulfides and this may be an important way to generate Cu (and other chalcophile element)-rich fluids.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Crustal-Derived LCT Pegmatites as Potential Critical Metal Sources in the Bas Draa Inlier, Western Anti-Atlas, Morocco

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Pegmatites are increasingly recognized as essential sources of critical metals required for the energy transition, fueling advances in battery technology, renewable energy infrastructure, and various high-tech applications. Given their strategic importance, pegmatite studies have become a focal point of research, though many questions remain about their formation and evolution. In the Bas Draa Inlier of Morocco's western Anti-Atlas, a prominent swarm of aplitic and pegmatitic dykes traverses Precambrian intrusions and metasedimentary rocks. These dykes, varying from a few centimeters to several kilometers in length, are composed of quartz, muscovite, feldspar, tourmaline, petalite, apatite, zircon, garnet, and gahnite. They exhibit strongly peraluminous characteristics, with mineralogical and geochemical features indicating their classification within the LCT (Li-Cs-Ta) pegmatite family. Specifically, the Bas Draa pegmatites show a low total rare earth element (REE) content (<500 ppm), and their mineral assemblage—including petalite, tourmaline, garnet, and gahnite—reflects enrichment in Pb, Rb, and Cs, alongside depletion in Ba and Nb on a primitive mantle-normalized multi-element plot. The petrogenesis of these pegmatites appears to be crustal anatexic, likely originating from the surrounding metasedimentary host rocks rather than nearby granites. This is further supported by their highly mafic tourmaline compositions (Schorl-Foitite), the presence of epidote, and distinct field relationships. The Bas Draa pegmatites thus represent a unique case of crustal-derived LCT pegmatites in the region, with promising implications for future sourcing of critical elements needed to sustain the global shift towards renewable energy.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Exploring Critical Raw Materials: Field and Petrographic Study of Imiter Aplite-Pegmatites in Early Ediacaran Greywacke Meta-sediments, Anti-Atlas, Morocco

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The growing demand for critical raw materials, especially for electric vehicle batteries, has refocused mineral exploration on rare-element granitic pegmatites. These pegmatites, rich in valuable commodities, have seen enhanced exploration targeting through geochemical studies. In the northwestern West African Craton, Li-rich pegmatites are widely exposed across the 600 km-long Anti-Atlas belt, containing several underexplored pegmatite fields. The Imiter Pegmatite Field, part of the extensive Pan-African metallogenic province, intersects the early Ediacaran Saghro Group basement with a prominent swarm of aplitic and pegmatitic dikes, oriented in NE-SW and NW-SE directions. Petrographic analysis of these pegmatites reveals a composition dominated by quartz, plagioclase, K-feldspar, muscovite, biotite, allanite, and sphene. These exterior pegmatites, associated with Bou Teglimt granitic plutons and hosted in metamorphic rocks, are linked to the late Ediacaran Large Magmatism Province, with an age range of 590 to 540 Ma. The Imiter pegmatites feature complex layering, internal zoning, and abundant muscovite-rich minerals, including Li-micas like lepidolite and/or amblygonite, marking them as valuable targets for exploration in fertile granites and rare-element pegmatites. The Imiter Pegmatite Field, a key region within the Saghro massif, requires detailed studies on crystallochemistry, petrogenesis, and exploration techniques to understand the metasomatic processes and geochemical changes caused by the intrusion of aplite-pegmatites into metasediments.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

The role of magma source and evolution in the formation of porphyry copper deposits – a comparative study in central Chile

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Copper is critical for the energy transition. With three-quarters of the world's Cu production coming from porphyry Cu deposits, improving our understanding of the magmatic-hydrothermal processes that form them is now more important than ever. Most studies of porphyry magma fertility have focused on ore-related intrusions, but little has been done on intrusions that formed under similar tectono-magmatic conditions and did not form economic deposits. The Andes of central Chile offers an ideal region for magma fertility studies because it hosts some of the world's largest porphyry Cu deposits (e.g. Rio Blanco-Los Bronces and El Teniente) along with coeval barren intrusions. We have collected and compared whole-rock and zircon chemical data from two supergiant deposits and three barren suites from Central Chile, covering a range of compositions and ages. Our results show that the ore-related and barren intrusions have similar zircon O-Hf isotopes indicative of a common magma source (arc mantle), but distinctive whole-rock (e.g. Y, Sr/Y) and zircon geochemical signatures (e.g. Eu/Eu*, P, ΔFMQ). Therefore, these differences are acquired and enhanced during magma differentiation and evolution by different processes (e.g., increase in water content, extensive fractionation) that are the key to porphyry Cu formation. These differences lead to their distinctive geochemical signature and allow discrimination between barren and fertile intrusions. We are developing a multimineral approach for magma fertility discrimination through the analyses of multiple magmatic-hydrothermal mineral phases (e.g., apatite, titanite, rutile), with the integration of these tools showing promising results as an effective method for porphyry fertility assessments.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

The Late Cretaceous explosive volcanism and facies distribution in Bolnisi district: insights into the lithological control on ore deposits, Lesser Caucasus, Georgia

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The Bolnisi district of the northern Lesser Caucasus continues west into the Eastern Pontides, Turkey. It represents one of the major mining districts within the Tethyan metallogenic belt. This beneficial geotectonic location of Bolnisi district which is part of Artvin-Bolnisi belt, reflected by its geological and facies diversity, volcanism type, and mineral deposit distribution. The Late Cretaceous (~87–71 Ma) silicic-dominated bimodal volcanism in this region resulted in mafic and felsic rock types, the latter being a major host of the ore deposits and prospects, and being defined locally as the felsic Mashavera and Gasandami suites. The existence of caldera structures in this region has been mentioned by various scientists. Our new study in Bolnisi district was focused on a new mapping project based on field and facies-oriented analyses. Different types of ignimbrites are described by the author in this region: welded, mon-welded, slightly welded, and crystal-rich ignimbrites. Thickness varies from several m up to 400-500 m maximum. Gas-escape pipes and accretionary lapilli horizons are observed in this thick ignimbrite. Pumice tuff with different sizes of pumice and sometimes with transition zones to fine ash material, ash fall, and accretionary lapilli thick (up to several meters) horizons is outcropping in this region; different types of breccias including the phreatomagmatic, phreatic, volcanic and sedimentary is observed and mostly connecting with explosive character. Explosive breccia and pumice-bearing rocks (including different types of ignimbrites and pumice tuffs) are good permeable rocks for fluid, where mineralization is mostly localized.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Exploration and Characterization of Copper-Silver Mineralization in the Ighrem Inlier: Case of the New Ouarmdaz deposit.

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The Anti-Atlas belts are globally recognized for their world-class metallic ore deposits, particularly their significant copper reserves. Over 200 copper occurrences have been identified within the Neoproterozoic to Cambrian cover of the Moroccan Anti-Atlas. The increasing interest of mining companies in these potential copper resources necessitates a more comprehensive understanding of these mineralization. Ouarmdaz is one of Sediment-Hosted Copper Deposit located southwest of the Precambrian Ighrem inlier. It is hosted along the contact between the Precambrian basement and the infracambrian cover Tata-Taroudant group, approximately 168 km east of the city of Agadir. Exploration field works in the study area have uncovered stratiform, vein-type, and cavity mineralization within the infracambrian formations (Tamjout dolomite and lower limestones). The stratiform mineralization includes copper carbonates (Malachite and Azurite) and chalcopyrite, ranging in size from millimeters to centimeters. The vein mineralization comprises massive chalcopyrite with a quartz-calcite gangue. The structures were mainly oriented NE-SW, with a dip of 30–50° toward the southwest. Mineralization in this area is mainly characterized by copper carbonates, including malachite, azurite and occasionally chrysocolla, along with sulfides such as chalcopyrite, galena, bornite and iron oxides. Secondary paragenesis is more abundant than primary ore, with malachite being the most prevalent mineral phase, occurring as coatings, filling fractures, and cavities alone or in combination with azurite, chalcocite, and iron oxides. **Keywords:** Ore deposits , Stratiform mineralization, Sediment-Hosted, Igherm, Anti-Atlas.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Matrix geochemistry unveils deep drivers of copper fertility across the Central Andes

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The green energy transition is driving a rapid increase in the demand for copper. Most of the world's copper accumulates in porphyry systems in magmatic arcs, yet porphyry copper deposits represent only the tip of the iceberg – the final, shallow portions of vertically extensive, complex magma systems that span the entire crust. Precursory processes occurring at depth in these systems are inferred to control the endowment of shallow mineralised intrusives, e.g., garnet fractionation at depth is considered to oxidise the melt, allowing the transport of copper to upper crustal levels. Here, we access deep fractionation across the Central Andes, Earth's most fertile continental arc, with laser ablation mass spectrometry of volcanic matrix (in situ LA-ICP-MS groundmass rasters). We focus on volcanoes in the main arc (Lascar stratovolcano, Cerro Overo monogenetic cone) as well as in anomalous settings that may enhance copper fertility, including an arc kink (Socompa stratovolcano, El Negrillar monogenetic field) and the back-arc (Tuzgle stratovolcano). The volcanic matrix has relatively evolved basaltic trachyandesite to rhyolite compositions with typical MgO of 1-5 wt.%, indicating that primary melts did not erupt, and instead were strongly modified through the crust. Trace element data reveal that the volcanoes located in anomalous settings record garnet fractionation. In contrast, the main arc volcanoes dominantly record amphibole signatures. Our work shows that isolating melt records using volcanic matrix can improve proxies for magma generation, differentiation and filtering relative to bulk rock compositions. We aim to develop fertility indicators for copper exploration in arc systems.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

The role of rhyolite melts in the petrogenesis of Tabenken Coal seam, North West Region Cameroon

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Coal is a vital natural resource, despite the importance of coal in the world, in Cameroon little is known about coal and very little published data on coal use and coal mining. In Cameroon, coal has been identified in Bali, Dschang, Fundong, Mamfe and Tabenken. The discovery of coal intercalated with rhyolites in Tabenken in Donga Mantung Division, More so, the discovery of hydrocarbon veins, in the rhyolites close to the coal is a course for concern. Detailed geochemistry, petrography and mineralogical studies were carried out on coal, rhyolites and coal bearing rhyolites. Major emphasis was placed on getting the temperatures of formation of rhyolites, since the emplacement of coal seam depends on temperature. To obtain the temperatures, zircon saturation temperature of magma was used and the formula M [(Na+K+2Ca)/ (Al*Si)] was used to obtain cation ratio, and Tzr12900/ln (Dzr) + 3.8 +0.85 (M-1) -273.15 to estimate the peak temperature experienced by the magma. From calculations, the plot of cation ratios (Na+K+2Ca)/ (Al*Si) against Zr with Zircon saturation line was done, these results reveals that the rhyolites deposited at temperatures ranging from 900°-1000°C. Comparing these temperatures with those at which coal liquefaction takes place industrially, which is between 220°-470°C using either direct or indirect coal liquefaction techniques in the presence of a catalyst, we can suggest that at the temperature 900°-1000° coal is capable of being transformed to liquid hydrocarbons in the absence of a catalyst.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Melt inclusion records of volatile and metal degassing at Brothers submarine volcano, Kermadec arc

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In recent years, studies have suggested that meals in seafloor massive sulphides at Brothers volcano (Kermadec arc) are degassed from underlying magma. To test this hypothesis, we measured the volatile contents (H_2O, CO_2, S, Cl: by Raman, SIMS and EPMA), sulphur speciation (by EPMA) and select trace metal contents (by SIMS) of glassy plagioclase-hosted dacitic Brothers melt inclusions (MIs). Measurable CO_2 was not found in MI-hosted vapour bubbles. The MIs are oxidised (S^{6+}/S^{total} ~0.8, fO_2 ~FMQ+2) and have variable CO_2 (3–264 ppm) and H_2O contents (2.3–5.1 wt%), recording degassing between ~50–200 MPa. Sulphur contents are low (≤350 ppm), reflecting partitioning into vapour and sulfides. Moderate metal contents (e.g., up to 53 ppm Cu) are retained by the dacitic melts due to oxidising conditions that minimise losses to sulfides. Chlorine contents (max = 6270 ppm) are among the highest known for any subalkaline arc magmas, but only minimal Cl has degassed to vapour. Hypersaline brine inclusions found previously at Brothers imply degassing of more saline fluids at later stages of crystallization than recorded by the MIs. Very high magmatic Cl/H_2O ratios and incompatible behaviour of Cl may eventually drive mushy parts of the system to brine saturation, releasing saline fluids that scavenge metals from the residual melt. Our work supports other evidence for magmatic contributions to massive sulfide deposits at Brothers, but suggests that most metals degas later than in large porphyry copper deposits.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Lithium Pegmatite Exploration in the Omeo Zone (NE Victoria, Australia): Evaluating Prospectivity Using Ta-Nb Oxides

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Lithium (Li) is a critical metal essential for green technologies, playing a key role in enabling the transition to a low-carbon energy future. It is primarily concentrated in closed-basin brines, volcanic clays, and lithium-caesium-tantalum (LCT) pegmatite deposits. Most Australian LCT pegmatites are located in Western Australia, such as the world-class Greenbushes Li-pegmatite deposit. Despite there is potential for additional pegmatitic deposits across Australia, as demonstrated by Li, Ta, Sn, and Nb exploration activities in Victoria, the exploration workflows for Li deposits remain poorly established due to their complexity of mineral assemblages, coupled with the limitations of geophysical detection techniques. Here, we focus on the Omeo Zone in northeastern Victoria (SE Australia), testing innovative characterisation and exploration workflow. Our investigation goes beyond conventional whole-rock composition methods by integrating microscopic-scale techniques (e.g., automated mineralogy, mass-spectrometry analyses) applied to indicator minerals such as Ta-Nb oxides. We examine mineralogy, textures and fine-scale compositional zoning patterns in Ta-Nb oxides hosted by mineralised and unmineralised pegmatites. Fractionation trends are characterised by an increase in the Ta/(Ta+Nb) ratio with minimal or no changes in Mn/(Mn+Fe), reflecting high Ta solubility in the silicate melt during fractionation. Mineralised pegmatites commonly host Ta-Nb oxides displaying distinct core-to-rim compositional variations (e.g., high Nb-low Ta core, high Ta-low Nb rim), while more complex zonations are recorded among barren pegmatites (e.g., oscillatory and patchy zonings). This research provides insights into the magmatic-hydrothermal history of Li pegmatites, elucidating Ta-Nb oxides fractionation and crystallisation processes to refine exploration workflows and more efficiently target Li resources.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Late sulfide saturation in the Valle Fertil deep crustal section, Argentina: implications for chalcophile cycling in arcs

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The oxidation state of sulfur in arc magmas controls the transport of chalcophile metals through the crust to be vented to the atmosphere or form magmatic-hydrothermal ore deposits. It is posited that early saturation of sulfide in arc magmas generates metal-rich sulfides which depletes ascending magmas in chalcophile elements. Despite this, arc magmas are the primary source of porphyry Cu deposits, suggesting that sulfide saturation in arc magmas is not detrimental to their ore-forming capacity. However, the timing of sulfide saturation relative to deep arc magma differentiation remains poorly described. We investigated the behaviour of sulfur in the Valle Fertil crustal section, Argentina where the deep to mid-crust of a palaeo-continental arc is exposed. With differentiation, cumulates transition from sulfide- and copper-poor to sulfide- and copper-rich suggesting that sulfides formed relatively late in the crystallization sequence. We tracked the valence state of sulfur across the deep crust using micro X-ray Absorption Near Edge Spectroscopy (µXANES) at the S K-edge in apatite, which can incorporate S^{2-}, S^{4+} and S^{6+}. We found that the deep crust was dominated by oxidised sulfur (S^{6+}), regardless of melt differentiation or pressure, indicating *f*O2 exceeding one log unit above the fayalite-magnetite-quartz buffer. We present a sulfide saturation model, which indicates that *f*O2 ~FMQ+2 can delay sulfide saturation sufficiently to produce intermediate magmas which escape chalcophile depletion through sulfide saturation. Such oxidized and metal-rich magmas may play a key role in delivering metal fluxes to Earth's atmosphere and porphyry-type ore deposits, which remains to be fully tested.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Halogen ratios as tracers of magmatic fluid release in the crust

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Porphyry-type Cu-(Mo-Au) ore deposits gain their metal budget from magmatic fluids, and chlorine is a key ligand facilitating metal extraction from magmas. Contrary to the conventional view, increasing amount of evidence suggests that significant masses of magmatic fluids are exsolved at greater crustal depths due to highly elevated dissolved water concentrations in arc magmas. As a corollary, significant fluid exsolution may also happen from relatively mafic melts. We present new data on the partitioning of chlorine, bromine and iodine between aqueous fluids and silicate melts as a function of pressure (*P=150–835 MPa*), temperature (*T=800-1000 °C*), fluid salinity (from ~ 3 to ~ 62 wt% NaCl equivalent) and silicate melt composition (basalt to rhyolite). Fluids and silicate melts were equilibrated in externally heated pressure vessel assemblies and piston cylinder apparatus. The composition of the quenched glasses were determined by Electron Probe Microanalysis (major elements + Cl) and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (major elements + Cl, Br, I), and the fluid compositions were derived by mass balance calculation. Results of key importance are: 1) the fluid/melt partition coefficients ($D^{f/m}$) systematically increase with increasing halide ion radius, and therefore Br/Cl and I/Cl ratios are tracers of fluid loss; 2) At low fluid salinities, all halogens increasingly partition into the fluid with decreasing *T* and with *P* increasing up to 400-500 MPa; however, their $D^{f/m}$ decrease above 500 MPa; 3) $D^{f/m}_{halogens}$ rapidly drop as the silicate melt becomes more mafic. Model equations capable to predict $D^{f/m}_{halogens}$ in *P*-*T*-compositional space were constructed.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Rapid fractionation of copper with magmatic volatiles in volcanic systems

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With evidence for hydrous volatile-rich evolution, saturation and degassing, active and well-sampled arc volcanoes like Soufriere Hills Volcano (SHV) on the island of Montserrat are targets where volatile partitioning and transport of metals out of the silicate melt can be assessed. SHV andesites entrain enclaves of more mafic composition formed at the interface between rising magma and stalled fractionated magma bodies. Previous $(^{210}Pb/^{226}Ra)_0$ isotope analyses (which track recent (<100 years) volatile loss or gain in the magmas) showed volatile capture by the enclave-forming mafic magma at the start of SHV's most recent eruptive episode, by contrast with the andesites with evidence of continual degassing. The samples were analysed for $\delta^{65}Cu$ as a monitor of Cu fractionation during transport between separate phases. The andesite lavas have uniform $\delta^{65}Cu$ values close to 0‰. The earliest enclaves however show quite negative $\delta^{65}Cu$ values (down to -2.5‰) and there is positive linear covariation of $d^{65}Cu$ with age. Correlation between ^{210}Pb-excess and negative $\delta^{65}Cu$ in the early enclaves suggests a fractionation mechanism for Cu relating to magmatic volatile phases operating at the beginning of the eruptive episode and waning with time. This also puts a time constraint of <100 years on this mechanism. Transport of Cu via exsolved fluid is unlikely as heavy $\delta^{65}Cu$ would be expected, rather than the negative $\delta^{65}Cu$ (and high elemental Cu) observed. A source of light $\delta^{65}Cu$ could involve stripping of Cu from magmatic sulphides in the deeper crust during periods of mafic magma recharge and fluid saturation during decompression.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Evolution of porphyry-fertile magmatic cycles inferred from trace element profiles in zircons

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Magmatic systems associated with supergiant porphyry Cu deposits (PCDs) undergo a multi-million-year maturation in the deep continental crust. This evolution is recorded also by zircon, the most used mineral to infer magma fertility in porphyry Cu systems due to its resistance to hydrothermal alteration. Nonetheless, zircon analyses are almost always limited to one or two spots and miss to convey information on changing magmatic conditions during its crystallization. This information is valuable to better understand the evolution of the fertile magmatic system and can be obtained through detailed core-to-rim profiles. We report nanoSims trace element (Eu, Gd, Ce, Ti, U) profiles in 48 zircons from 8 samples of pre- to syn-mineralization magmatic rocks associated with the supergiant Llurimagua PCD (Ecuador). Zircons span a range of ages between ~23 and ~6.3 Ma. Mineralization occurs at the end of this magmatic cycle, typical of supergiant PCDs, between ~7.28 and ~6.22 Ma. Between ~23 and ~10 Ma, profiles indicate zircon crystallization from magmas cooling at shallow crustal levels in concomitance with plagioclase fractionation. The cores of the ~23-10 Ma zircons also indicate that these zircons crystallised from magmas that have progressively evolved at deep crustal levels through time, under increasing PH2O and fO2 conditions. After ~10 Ma zircon profiles display both cooling and heating patterns suggest the onset of a more dynamic magmatic plumbing system characterised by recharges and suggesting an increased magma transfer from deep to shallow levels, which is ultimately responsible for the subsequent mineralization from ~7.3 to ~6.2 Ma.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Emplacement depth and ore metal extraction: The effect of pressure and temperature on the fluid/melt partitioning of ore metals in magmatic-hydrothermal systems

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Porphyry-type ore deposits supply most Cu and Mo, and significant amounts of Au and Ag for our society, making the understanding of their formation essential to the targeted exploration for these metals, some of which are critical for the green energy transition. Several recent studies proposed the onset of fluid exsolution in porphyry ore-related magmas to take place at mid to lower crustal depths, affecting the metal, Cl, and S concentrations of ascending magmas; therefore, requiring accurate constraints on the influence of *P* and *T* on the fluid/melt partition coefficients ($D^{f/m}$) of Cu, Ag, Au, and Mo in these systems. To this end, experiments were conducted at *P* = 150–700 MPa (~5–25 km depth) and *T* = 750–950 °C. Synthetic rhyolite melts were equilibrated with S-free fluids containing 5.5 and 37 wt.% $NaCl_{Eq}$ chlorides in Au-Ag-Cu alloy capsules and the equilibrium fluid was trapped in quartz cylinders in the form of synthetic fluid inclusions. Experiments were run using cold-seal molybdenum-hafnium carbide pressure vessels ($P \leq$ 300 MPa) or a piston cylinder apparatus (P > 300 MPa). $D^{f/m}$ values of Cu, Au, and Ag decrease with increasing *T; P* shows negligible effects on $D^{f/m}_{Ag}$ and $D^{f/m}_{Au}$. $D^{f/m}_{Mo}$ is unaffected by *T* and increases with *P* only at low fluid salinity. Solubility data indicate that for Cu, Au, and Ag, solubility in the fluid imposes the *T*-dependence of fluid/melt partitioning, and that Au becomes highly insoluble in both fluid and melt phases in S-free systems below 750 °C.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Exploring the volcanic connection in porphyry copper systems

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Volcanic activity is thought to preclude the formation of porphyry copper deposits (PCDs). This is because these deposits require a large effective volume of magma in the shallow crust, which is capable of exsolving large amounts of metal-bearing hydrothermal fluids. It is therefore generally assumed that any coeval or sub-coeval large-scale volcanic activity would terminate ore deposition as the required volatiles and metals are vented to the atmosphere. However, there are a limited number of known mineralized porphyry systems with extant coeval volcanic units where such relationships can be studied. The Jurassic Yerington district, USA, is an exception, with tilting exposing a unique cross section of the volcanic units, deposits, and batholith. We investigate the relationship between PCDs and volcanic eruptions by examining the petrochronology of zircon in coeval volcanic units associated with the Yerington batholith, using in-situ LA-ICP-MS and high-precision CA-ID-TIMS U-Pb methods. Known as the Fulstone Spring volcanics, these units consist of a thick pile (~1.5 km) of andesitic-dacitic ignimbrites and lavas. Geochronological data shows that these volcanics erupted both pre- and post-mineralisation, but show a <1 Ma gap coinciding with the emplacement of porphyry dikes associated with the copper mineralisation. Zircon trace element compositions and Ti-in-zircon temperatures as well as whole-rock compositions diverge between the pre- and post-mineralisation volcanics and mineralising porphyries, indicating protracted melt evolution and recharge processes in the shallow magma reservoir. We conclude that a resurgence of volcanic activity may have played a role in reducing or terminating copper mineralisation in the Yerington PCD.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Partitioning and outgassing of chlorine during ascent of a rhyolite magma from physical modelling and natural glass data

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The behaviour and availability of magmatic volatile components (e.g. Cl, a metal complexing agent) are key controls on the transport and concentration of valuable metals such as Cu. The evolution of volatile phase composition, and the ultimate destination of the volatile components (and metals), will differ for closed and open-system degassing. The evolution from closed to open-system degassing may permit fluids to leave the conduit into the surrounding wall rock by lateral transport if there is sufficient conduit overpressure. Silicic hydrous magmas rich in Cl are of interest for their potential to concentrate metals in fluids. We apply a 1D conduit magma-ascent code to model H_2O-Cl degassing of a rhyolitic magma ascending up a conduit from pressures of ~200 MPa to 10 MPa. We use a suite of volatile data from the 2012 Havre eruption (melt inclusions up to 4500 ppm Cl and 6 wt.% H_2O, down to 1000 ppm Cl and 0.7 wt.% H_2O in the matrix glasses) to set the degassing endmembers. The model further determines conduit overpressure and the flux of lateral outgassing into the crust. We then apply a geochemical model, tracking melt-fluid partitioning of Cl, to estimate the concentration of particular metals (e.g. Cu, Au) in the outgassing fluids. We show that, while lateral outgassing by conduit overpressure is most prevalent in crustal depths less than 1000m, the highest metal concentrations and likelihood of brine accumulation occurs at depths of several km, and closer to initial magma storage regions where melt-fluid partitioning is greatest.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Understanding the petrogenesis of Li-rich magmas: a case study of the Li-granites of Cornwall, UK

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Lithium-enriched granites are of increasing interest globally due to the explosion in demand for lithium (Li), primarily due to its importance within Li-ion battery systems. However, many questions remain about the co-genesis of Li-rich and Li-poor magmas, such as in the Cornubian batholith (Cornwall, UK). Previous models have required multi-stage melting [1] and/or unique source lithologies [2] to explain this co-occurrence. This study utilises advanced phase equilibria modelling to produce a model which bypasses these previous requirements, using the c.290-270 Ma granites of the Cornubian batholith as a case study. Our modelling broadly agrees with previous studies, which showed that the granites (G1-G5) were sourced by melting of a greywacke at pressures of c.3-6 kbar [2]. However, to explain the co-genesis of both Li-poor (G1-G4) and Li-rich (G5) granites within a single melting event, we present a new model invoking both fractional melting and the co-presence of 'standard' and F-rich (Fluorine-rich) biotites within areas of the source greywacke. G1-G4 melt extraction occurs after the breakdown of 'standard' biotite, with G5 melts subsequently extracted after the breakdown of the F-rich biotites. These F-rich biotites are stable to higher temperatures [3] and have a much greater biotite-melt D_{Li} [4], which allows for the retention of Li during G1-G4 melting, followed by the release of this Li after breakdown, during G5 melting. *References:* [1] Koopmans et al. (2023) Geology 52:7-11; [2] Simons et al. (2016) Lithos 260:76-94; [3] Brigatti and Guggenheim (2002) Rev Mineral Geochem 46:1-97; [4] Beard et al. (2025) VMSG-MDSG 2025

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Critical-Ireland: Using Irish mafic intrusions as a natural laboratory to understand PGE mineralising processes

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The European Commission has identified Platinum Group Elements (PGEs) as “critical raw materials” which are essential in modern green technologies but have a high risk to supply, urgently requiring innovative research to assist in locating new deposits. Palaeogene igneous centres in the north of Ireland have been identified as promising European PGE exploration targets and provide a unique opportunity to understand mineralising processes due to excellent bedrock exposure and the availability of high-resolution Tellus geophysical data. *Critical-Ireland* is an ongoing multidisciplinary project which is using these Irish centres as a natural laboratory to interrogate the first-order mechanisms of PGE deposit formation in layered mafic intrusions and dyke/sill complexes. This presentation will give a summary of research progress to date, highlighting the link between discreet project components and demonstrating how the research team are using Irish Palaeogene centres to target outstanding issues in our current understanding of PGE deposit formation. This includes: using high-precision trace element data to characterise compositional/thermal perturbations and PGE enrichment in the Irish lithospheric mantle; using textural and geochemical datasets to constrain the complex multi-stage crustal processes which generate mineralisation in mafic intrusions; and developing global physical (i.e. thermal) models to simulate magma-country rock interactions during crustal magma transport. Project results will not only improve our understanding of physicochemical processes in ancient mineralised magma systems but will also inform future interpretations of the mantle/crustal processes operating beneath active volcanoes today.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

Magmatic sulfide saturation and ore formation in the Konya Volcanic Belt, Western Anatolia

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We use trace element systematics of magmatic sulfides and volcanic rocks of the Konya Volcanic Belt, hosting, among others, the Doğanbey porphyry-Cu-Au prospect and the Inlice epithermal-Au deposit, to investigate the effect of magmatic sulfide saturation to the Cu and Au fertility of the ore-forming systems. A general decrease in whole rock Cu, PGE, Cu/Ag, Se and S noted with magmatic evolution and coupled with petrographical observations, confirm that the system underwent extensive sulfide saturation with sulfides found in both andesites and dacites characterised by wide ranges of SiO_2=56-69 wt.%, Cu=4.6-62 µg/g, and Cu/Ag=182-1785. Nonetheless sulfide occurrence and composition varies. Sulfides composed of mostly pyrrhotite (± pentlandite, chalcopyrite) yielded low Cu and Au contents (EPMA: Cu_{med}=0.46 wt.% and LA-ICP-MS: Cu_{med}=1.3 wt.%, Au_{med}=0.089 µg/g), and were hosted by early crystallising phenocrysts found in the majority of the volcanic products. In contrast, late sulfides composed of chalcopyrite (± bornite, digenite) and corresponding to high Cu contents (EPMA: Cu_{med}=32-56 wt.%), were hosted exclusively by magnetite found only in andesitic–dacitic lavas. Meanwhile, bulk PGE contents confirm that all magmas (seemingly barren and mineralised) are extremely depleted (Pd/Pt_{med}=1.61) relative to other porphyry Cu-Au forming magmas (Pd/Pt=7-60). These results suggest that regardless of the timing and nature of the sulfide phase saturating, as well as of the initial metal-poor source, Konya magmas produced an economic deposit as well as numerous other prospects with varying type and extent of mineralisation. This in turn points out to the importance of additional processes that promote ore-formation in the area.

Theme: 4. Minerals for the energy transition

Session 4.1: Tapping into magmas for the building blocks of the renewable energy infrastructure: from petrogenesis to exploration

Allocated presentation: Poster

FROM HYDROCARBONS TO RENEWABLES: THE STRATEGIC IMPORTANCE OF CRITICAL MINERALS IN ALGERIA'S ENERGY TRANSITION PLAN (2024-2034)

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At the moment when oil revenues continuously decrease for Algeria, developing a diversified energy matrix is an urgent need for the country. That energy matrix should be able to maintain satisfactory economic growth and cope with increased energy demand. In this perspective, Algeria has focused the attention on the so-called critical minerals, among which lithium, cobalt, nickel, platinum, copper, and some rare earths can be pointed out. These are the minerals required in renewable technologies manufacturing: solar panels, wind turbines, and energy storage systems are very important for transitioning into a renewable energy economy. This paper reviews the state of current exploration and mining activities of such mineral resources in Algeria, based on geological and morphogenetic processes that support their formation. Additionally, it analyzes the existing policies and regulations that control mining and mineral resource management, with a view to identifying how such frameworks can help renewable energy initiatives of the nation. Targeted investments in supply chains of critical minerals could increase economic resilience for Algeria while at the same time fast-tracking its efforts towards renewable energy targets. The report calls for mineral resource management policies to be included in the overall energy transition plan of Algeria, whose ambition is to exceed 30% by 2030 concerning the share of renewable energy. This paper brings out the need to adopt an integrated, sustained approach to exploration and development of minerals. Mineral resource management in harmony with national energy strategies will, therefore, enable Algeria to transition seamlessly from hydrocarbons into renewables throughout the next decade while ensuring environmental sustainability besides economic stability and growth. It recommends proactive policy suggestions aimed at fostering coordination among government agencies, the private sector players, and international partners to handle these high ambitions. **key words**: Algeria, Energy Transition, Renewable Energy, Critical Minerals, Lithium, Cobalt, Nickel, Platinum Group Elements (PGEs), Copper, Rare Earth Elements (REEs), Mineral Resources.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Talk [Invited]

Subsurface imaging of the Great Sumatra Fault and Mount Kerinci (Indonesia) using Nodal Ambient Noise Tomography

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The Great Sumatra Fault propagates through the central region of West Sumatra, Indonesia. The combination of tectonically driven trans-tensional deformation and lithology promotes the upwelling of magmatic fluids into the intermediate- to upper-crust, forming notable volcanic, hydrothermal, and geothermal subsurface systems. Widespread surface manifestations include hot springs and fumarolic activity occurring within the valley and on the shoulders of the Kerinci volcano. We used a network of 212-nodal 3-component seismic nodes to produce a high-resolution Nodal Ambient Noise Tomography (NANT) to identify subsurface reservoirs, regions of fluid transfer, and enhancements of permeability. The survey area of 400km^2 consisted of a dense distribution of 182 instruments around the populated area of Muara Laboh, and 6-antenna-arrays of 5-seismic-nodes, positioned around the eastern flank of Mount Kerinci. We derived Empirical Green's functions from the cross-correlation of ambient seismic noise from Rayleigh waves, and determined dispersion curves based on the Frequency Time Analysis (FTAN) technique. Group velocity maps were calculated using a nonlinear multi-scale inversion technique and finally we performed a depth using a McMC-transdimensional Bayesian inversion to produce a 3D S-wave velocity model. The inverted S-wave velocity model highlights a number of varying low- and high-velocity domains, often with sharp transitions. We delineate intermediate-velocity transition zones on the shoulders of the low-velocity domains, and suggest that this could represent the boundaries of intrusive bodies containing high-temperature geothermal fluids. One of these zones is located below the current Muara Laboh geothermal field and the others could represent ideal locations of future geothermal energy prospection.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Talk

Iron Sharpens Iron: Using Hydrothermal Alteration Data from Crystalline Basement to Illuminate Modern Sub-Volcanic Geothermal Reservoirs

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This study investigates hydrothermal alteration processes in crystalline basement terrains, providing an analogue for sub-volcanic geothermal reservoirs affected by faulting and hydrothermal activity. In these basement rocks, hydrothermal fluids interact with primary minerals, leading to significant alteration and the creation of secondary porosity above 30% and permeability values reaching over 10^{-12} m^2. Key alteration features include the replacement of mafic minerals such as biotite, pyroxene, and amphibole by chlorite and epidote, indicative of high-temperature (200–300°C) hydrothermal processes. Altered granites, migmatites, and gneisses display a consistent sequence of mineral transformations, including garnet-biotite-chlorite, quartz dissolution, and the precipitation of zeolites, prehnite, and calcite, which further alters porosity and permeability. Fault networks within these rocks provide pathways for fluid circulation, driving alteration and contributing to the formation of crystalline reservoirs. High-resolution CT scanning reveals up to 96% pore connectivity in the most altered rocks. Additionally, drone photogrammetry reveals kilometer-scale networks of faults and fractures transecting plutons and batholiths, while cross-flow pumping tests show hydraulic connection over distances of at least 500 meters, emphasizing the large-scale hydraulic connectivity of these fault zones. The study underscores the dynamic and multi-stage process of crystalline reservoir formation, involving fracturing, alteration, and reactivation under varying tectonic and thermal conditions, a common feature of sub-volcanic environments. These findings offer valuable insights into sub-volcanic geothermal systems and their potential conventional reservoirs, with implications for constructing unconventional EGS in similar settings worldwide.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Talk

State of Knowledge regarding the State of Hawaii's Geothermal and Carbon Storage Resources (USA)

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Still today very little is known about the extent of geothermal resources across the State of Hawaii, and the first project to characterize carbon storage in Hawaiian basalts is underway. This presentation will review the US Department of Energy funded Hawaii Play Fairway project, which took place from 2014-2020, produced the first statewide geothermal resource assessment since the 1980s, and culminated with slim-hole drilling of the deepest well off of Hawaii Island on the caldera rim of Lanai volcano. The presentation will also describe ongoing projects.by the Hawaii Groundwater and Geothermal Resources Center related to geothermal resource characterization, as well as a current project characterize downhole conditions in terms of carbon storage potential in the ~3.5 km deep Hawaii Scientific Drilling Project (HSDP) well in Hilo Hawaii.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Talk

Controls on the Southern Andean Nevados de Chillán Geothermal System

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The active Nevados de Chillan volcano in the Southern Volcanic Zone of Chile presents evidence of an abundant geothermal reservoir but constraints on its size, form and depth have so far remained elusive. To remedy this, we report on combined results from structural geology surveys, experimental rock physical property analysis, surface temperature monitoring as well as clay mineralogy and finite element method temperature flow modelling. The basement of the volcano consists of four main lithologies; granodiorites with porosities of <2% and stiffnesses around 80 GPa, softer (between 50 to 70 GPa) contact hornfels with porosities <3%, diorites with a large range of porosity from around 3 to 8% and stiffnesses ranging 30 to 65 GPa, and volcaniclastic units with porosities as high as 13 % and stiffnesses as low as 10 GPa. A series of high-angle sinistral, and low angle reverse, faults appear to control local fluid flow as evidenced by links between high temperatures (95°C) and intense argillic hydrothermal alteration in lineated surface fumarole features. Quantification of fracture attributes, from specimen to outcrop scale, their respective response to crustal stress and their tendency to dilate or slip, allowed us to hypothesize that the current reservoir resides predominantly in granitic rocks of Miocene age. Numerical and analytical modelling indicates heat fluxes ranging from 0.1 to 0.7 W/m^2 ^and the estimated geothermal energy potential of the system is around 39±1 MWe.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Talk

Seismicity patterns and their source regions at Krafla (N-E Iceland)

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Krafla is one of the five central volcanoes of the Northern Volcanic Zone in north-east Iceland and has been utilised for decades for geothermal energy production. Thus, the volcano and its geothermal system have been monitored and imaged extensively with various geophysical methods to better understand this complex geological setting scientific and also industrial interests. With a ten-year dataset of 30.000 manually picked seismic events from a local permanent 12 station seismic network owned by Landsvirkjun and operated by Iceland GeoSurvey, and a very dense temporary array of 98 seismic nodes deployed for one month in 2022 in the center of Krafla caldera, we imaged P- and S-wave velocity structures of the volcano by using local earthquake tomography and analysed the relocated seismicity patterns. To decipher if these events can be attributed to different sources, we use an unsupervised machine learning approach to cluster the events based only on the polarity of the P-onset, to make sure that effects related to different propagation paths in the clustering are minimized. With this approach, events originating from diffuse seismicity clouds can be attributed to different sources, using existing focal mechanisms, available GPS data and variations in the re-injection rates at wells of the geothermal powerplant. By applying this method to the ten-year data set, we hope to gain a better understanding of when and where structures are active, and thus offer insights if volcanic forcing such as inflation/deflation or external forcing such as regional seismicity and anthropogenic influence trigger certain seismicity patterns.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Talk

Tracing hydrogeochemical processes in the mineral waters of Furnas volcano

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Furnas volcano, one of the three active central volcanoes of São Miguel (Azores), hosts mineral waters with significant physicochemical variability. These waters are categorized as hyperthermal (89.4 - 95.4 °C), thermal (29.9 - 70.0 °C) and cold (14.2 – 21.4 °C). Most are Na-HCO_3 with neutral to slightly acidic pH, except one sample with a SO_4-Na composition and low pH. Major element composition is primarily influenced by rock leaching and volcanic inputs. Volcanic inputs comprise two distinct environments: acid-sulfate boiling pools, formed by steam heating and H_2S oxidation, and neutral-HCO_3-Cl waters, where bicarbonate waters mix with deep neutral chloride fluids. Water-rock interactions contribute with lithium, iron, aluminum, rubidium, and strontium, while volcanic inputs provide boron, arsenic, antimony, and tungsten. Strontium isotopes reveal equilibrium with the host rock, with no seasonal changes or incongruent dissolution detected. Rare earth elements generally match local rock patterns, with light REEs enrichment over heavy REEs and negative europium anomalies. Positive Eu anomalies in the hyperthermal waters from the Village, may reflect rock weathering at temperatures exceeding 250 °C, due to the contributions of the deep fluids, while in the thermal and cold waters can result from reducing conditions.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Geothermal systems and carbon storage in Tunisia

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In Tunisia, subsurface Cretaceous magmatism is regularly present as lava flows, intrusions and pyroclastic materials which were recorded at different Cretaceous lithostratigraphic intervals. The spatiotemporal distribution of magmatic events indicates their close association to major faults corridors which were reactivated by regional field constraints. For that, magmatism is found alongside deeply rooted faults where crustal melting was activated (Laridhi Ouazaa 1994; Matoussi Kort 2008). In this area, magmatic activity is understood to be associated to increasing heat flow and fluid migration (Matoussi Kort et al. 2008, 2009). In addition, several boreholes, drilled in the area, have frequently shown different gas occurrences associated to different Cretaceous intervals. For that, the present study will try to shed some light to the possible linkage between Cretaceous magmatism, hydrothermalism and such gas expressions in Eastern Tunisia. This paper, using subsurface data from seismic reflection (Geophysic, Bedir 1990), Geothermal data and studying selected samples collected from drilled boreholes in Tunisia, discusses: (i) structural and petrological evidence for fluid infiltration during cooling of Cretaceous magmatism in Eastern Tunisia; (ii) the impact of both heat and chemical elements income (associated to the magmatic rocks genesis) on the neoformation of new mineral phases within the enclosing sedimentary beds; (iii) the different CO2, H2S, CH4 and N2 gas expressions in the area and tries to identify their origin using carbon stable isotope data.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Lithospheric Thermal Structure as a Key Regulator of Intraplate Magmatism: Insights into High-Grade Geothermal Resources

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Geothermal energy is considered a key future energy source due to its widespread availability, stability, safety, and low carbon emissions. High-temperature geothermal resources (above 150ºC) are mainly found at plate boundaries, often linked with magmatic activity, while intraplate regions, especially densely populated areas, typically have fewer high-temperature geothermal resources. In the In the Northeast China, Cenozoic basalt is common, with intraplate magmatic rocks around the Songliao Basin and surrounding NE-NNE rift systems. Volcanic activity since the Quaternary also surrounds the basin. This study simulates magmatic activity and finds that the crust's thermal structure significantly influences magma emplacement. A cold, rigid crust hinders magma ascent, while a warm, softening crust allows magma to erupt. An optimal Moho temperature supports prolonged magma residence In the Songliao Basin, the Moho temperature is intermediate, suggesting the potential presence of concealed magma chambers. The paper proposes a model identifying "sweet spots" for intraplate basaltic geothermal resources, where magma chambers might exist below the surface, even without volcanic activity. This research improves understanding of magma intrusion patterns and supports global exploration of concealed high-temperature geothermal resources. Preliminary global Moho temperature calculations can aid in identifying thermal anomaly

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Geothermal Exploration of Gran Canaria Island (Canary Islands) using Ambient Noise Attenuation Tomography

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Gran Canaria is the third-largest island by area and height of the Canary Islands, with two distinct geological regions: the oldest region in the southwest (Paleo-Canarias), and the earliest in the northeast (Neo-Canarias), where all Holocene volcanic eruptions occurred. Due to its volcanic history, Gran Canaria may have geothermal resources that could enhance renewable energy in the Canary Islands. This study aims to use Ambient Noise Attenuation Tomography (ANAT) to obtain a high-resolution intrinsic attenuation model and identify anomalies linked to active geothermal reservoirs. To implement ANAT, 28 temporary broadband seismic stations were deployed, and data from the permanent seismic network operated by INVOLCAN were also used. We followed the methodology described by Cabrera-Pérez et al. (2024). First, standard data processing was applied to retrieve Empirical Green's functions (EGF) from ambient noise cross-correlations. Intrinsic attenuation for each EGF was calculated across multiple frequencies using the lapse-time dependence method, which evaluates attenuation based on coda window length at different onsets of the cross-correlation coda. Next, 2D attenuation maps for various frequencies were derived using linear inversion with sensitivity kernels. Finally, depth inversion was performed to obtain 1D attenuation models for multiple geographic points, interpolated into a 3D mesh. Preliminary results show high-attenuation zones in the eastern and southern parts of the island, coinciding with anomalies observed in previous geophysical, which could be related to active/fossil geothermal reservoirs. Cabrera-Pérez, et al. (2024). 3-D intrinsic attenuation tomography using ambient seismic noise applied to La Palma Island (Canary Islands). Scientific Reports, 14(1), 27354.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Cenozoic volcanism in Northeast China and its implications for geothermal systems

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Since the Cenozoic, volcanism in Northeast China has been distributed along the periphery of the Songliao Basin, while there has been no volcanism within the Songliao Basin, which has attracted extensive attention from researchers. To explain such phenomenon, a 2D visco-elasto-plastic model is established to model the ascending process of intraplate magma through the lithosphere, and study the influences of the lithospheric thermal-rheological structure on magma movement. The numerical simulation results indicate that with the increase of the temperature of the Moho (Tm), magma migration presents four situations: 1) at low Tm, the cold rigid crust will hinder magma ascent; 2) As Tm increases, the crust weakens, and magma directly penetrates the crust and erupts from the surface; 3) At appropriate Tm, magma invades the upper crust, forming hidden magma chambers that heat the surrounding rocks until the magma has completely cooled down; 4) at high Tm, magma will only extend laterally at the bottom of the crust. Situation 3) is most conducive to the formation of magma-type high-temperature geothermal systems. Additionally, we calculated the lithospheric thermal structure based on heat flow data and showed that Tm in the Songliao Basin is very high, much higher than its surrounding areas, which maybe an important reason for the lack of Cenozoic volcanism within the basin. Nonetheless, the high heat flow and the hot crust are favorable for the formation of low-medium temperature geothermal system of conductive type in the basin.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Forward Modeling and Inversion Techniques for Geothermal Reservoirs using Differentiable Programming in Julia

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Understanding and predicting the behavior of geothermal reservoirs in magmatic systems is critical for advancing sustainable energy production. These reservoirs are influenced by interactions between magmatic heat sources, fluid flow, and host rock deformation. To enhance predictive capabilities, we here develop a new forward and inverse modeling code to simulate fluid migration and host rock deformation within porous, confined aquifers. Our approach leverages the adjoint method to optimize parameter sensitivity analysis, significantly reducing computational demands compared to traditional inversion techniques. To simplify the development of our new poro-visco-elasto-plastic code we utilized the Julia programming language which is differentiable, yet very efficient, and allows to develop software by combining different composable packages. We employed the GeoParams.jl package to implement visco-elasto-plastic rheologies and solve coupled fluid-rock interactions under non-linear Darcy and incompressible Stokes-flow regimes. The framework is demonstrated using a representative setup of the Eifel volcanic region, highlighting its applicability to understanding geothermal systems influenced by potential active magmatic processes.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

The geothermal systems of Lipari and Salina islands (Aeolian Islands, southern Italy): a preliminary geochemical and geophysical perspective within the IRGIE project

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Assessing the potential and possible exploitation of geothermal resources is an essential step in a global climate change scenario that demands a transition to renewable resources. This could enable the energy autonomy in those remote areas, such as the small volcanic islands of the Aeolian archipelago (southern Italy), which are currently dependent on fossil fuels. This is the main topic of the IRGIE project, which aims to provide an inventory of the geothermal resources of the Aeolian Islands. In this study, the results of geochemical and geophysical surveys carried out at Lipari and Salina islands are presented. Lipari Island, where 24 water and gas samples were collected, shows a widespread thermal anomaly, with thermal springs (temperature up to 60 °C), fumarolic activity (over 90 °C) and gaseous emissions on the western part, and with several wells with temperature between 23 and 49 °C on the eastern part. The water samples show different compositions produced by multiple geochemical processes, such as water-rock interaction, seawater contribution, input of CO_2-rich fluids and steam heating. At Salina Island, where 6 wells and 2 gaseous emissions were sampled, the waters instead display temperature up to 27.8 °C on the northern part. The upcoming completion of the electromagnetic geophysical surveys on both islands, to be integrated with the geochemical data, will make it possible to identify the areas of greatest permeability and fracturing (likely the western side of Lipari) and to develop and realize conceptual models of geothermal circulation.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Quantifying mass and heat transport by hydrothermal fluid flow in a caldera setting

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Hydrothermal systems in caldera settings are potential targets for geothermal energy production. Increased permeability within the bounding ring fault that confines the caldera may represent preferred fluid flow pathways. To explore the spatio-temporal evolution of mass and heat transport within both the ring fault and the caldera infill, we conducted three-dimensional numerical simulations of hydrothermal fluid flow in the vicinity of a cooling magma chamber emplaced at 3 km depth. A cone-shaped, inwardly dipping high-permeability zone located above the intrusion represents the bounding caldera ring fault. Our results show that ~20–30 % of the total energy transport to shallow depths <1.5 km is accommodated by the high-permeability ring fault. This fault-focused energy transport occurs over a relatively short timescale (~5 kyrs) when the cooling magma chamber feeds hot fluids directly into the fault plane, leading to near-surface boiling zones. With increasing magma cooling and an associated shrinking heat source, upflow zones shift towards the caldera centre forming a hydrothermal plume. This plume accommodates ~60–70 % of energy transport to shallower depths <1.5 km over the first ~20–30 kyrs model time. Preliminary results indicate that energy released from the crystallised magma chamber remains stored within the geothermal reservoir at greater depth and is gradually transferred towards the surface via hydrothermal convection, forming a long-lived geothermal system. Our simulations suggest that ring faults can be key structures that transiently localise increased mass and heat transfer over a hundreds of years period, however, they may become less significant on geological timescales.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Shear-waves velocity structure of the Domo de San Pedro, Mexico from Ambient Noise Tomography

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We present a novel 3-D shear-wave velocity model for the Domo de San Pedro (DSP) complex in western Mexico retrieved from ambient noise analysis. The volcanic system, which hosts a high-enthalpy geothermal reservoir, is investigated by inverting group velocity maps derived from empirical Green's functions, obtained by cross-correlating continuous seismic signals recorded over ten months by 20 temporary broadband stations. The resulting velocity model reveals features down to 3.5 km depth and show the regional relationship between the DSP and nearby volcanic systems within the Jalisco Block and neighbouring domains. The velocity model shows the structural controls exerted by the tectonic boundaries between these volcanic complexes. The most important finding of this study is the identification of a low-velocity volume associated with the geothermal reservoir and a fluid-rich, fractured region underlying the DSP, which extends southwestwards for several kilometers. This low-velocity anomaly is separated from the shallow DSP structures by a thin clay cap, consistent with previous studies. Our results demonstrate that ambient noise imaging is an effective technique for characterizing geothermal areas and identifying generalized structural features that can help to identify promising targets.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Integrated geophysical modelling for geothermal exploration on Pantelleria Island

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Pantelleria Island, in Southern Italy, has significant potential for geothermal energy development due to its high geothermal gradient (>150 °C/km), active CO_2 emissions, and evidence of past volcanic resurgence. This study seeks to advance the understanding of the island's geothermal system through high-resolution gravity modeling. A comprehensive gravity survey was conducted, integrating existing on-land datasets with 130 newly acquired stations and offshore gravity data extending up to 30 km from the coast, resulting in a dataset of 1,050 measurement points. The combined data enabled the production of Free-Air and Bouguer anomaly maps with a spatial resolution of approximately 3 stations per km^2. These maps revealed significant horizontal density variations, correlated with subsurface geological structures. Edge analysis techniques, such as the Total Horizontal Derivative (THD), were applied to detect horizontal density contrasts, highlighting key stratigraphic and structural boundaries. These findings provided essential input for gravity data inversion, enabling the construction of a detailed 3D gravity model. The inversion process incorporates prior geological knowledge derived from borehole data, interpretations of reflection seismic data and a 3D resistivity model derived from magnetotelluric surveys. This multidisciplinary approach provides new insights into Pantelleria's geothermal system and highlights the island's potential for sustainable energy development. The results underscore the importance of integrated geophysical methods in geothermal resource assessment, contributing to the advancement of renewable energy applications.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Seasonal variability in hydrogeochemistry of Fogo volcano mineral waters

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A total of 10 mineral waters samples from Fogo volcano were collected during February and August 2022, in order to ascertain seasonal variations in their chemical and isotopic signatures. The thermal waters temperatures ranged from 27.2 to 58.4°C in winter and 28.2 to 58.4°C in summer, generally with lower pH values in both seasons. Cold waters temperatures ranged between 13.0 and 21.2°C in winter and 13.5 and 21.3°C in summer. A negative correlation between pH and temperature reflects the volcanic input, while electrical conductivity and bicarbonate concentration show a positive correlation linked to rock weathering. These waters are predominantly Na-HCO_3, with one sample classified as Na-HCO_3-Cl, showing minimal variation in the major components. Rare earth elements patterns resemble local rocks, though the majority present europium anomalies, either positive or negative. Positive Eu anomalies seem to be associated to rainwater recharge, which depicts the same spike, that fades during summer due to higher rock-water interaction, while negative Eu anomalies are linked to incongruent dissolution of the rock, with preferential dissolution of minerals such as pyroxene and amphibole. Strontium isotopes show different behaviors across samples, some showing stability and other exhibiting seasonal shifts. Samples with fluctuating $^{87}Sr/^{86}Sr$ ratios also display variable REE patterns, reflecting incongruent dissolution of the rock.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Unraveling hydro-fracturing mechanism: Is the analysis of induced-seismicity alone sufficient?

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In Enhanced Geothermal System (EGS) the goal is to create fluid circulation pathways for the heat production. In this respect EGS are field-lab scale of hydrothermal systems at volcanoes. Injection experiments at EGS are designed to induce hydro-shearing, where the fluid over-pressure induces either seismic and aseismic slip on pre-existing fractures; or hydro-fracturing where instead the fluid over-pressure exceeds the minimum principal stress and create tensile fracture propagating from the borehole injection point. Induced seismicity is recorded during these controlled experiments where fluids are injected following a prescribed protocol to build a reservoir via intense fracturing. However, even in designed injection experiments with a good knowledge of the stress field and rock properties, the fracturing response of the host rocks is difficult to decipher. We here have focused on the 2022 injection experiment performed at the Utah Frontier Observatory for Research in Geothermal Energy (FORGE). We have analyzed a high-resolution catalog of earthquakes recorded during the stimulation test at FORGE 2022. We analysied the spatial and temporal features of the seismicity cloud with respect to the in-situ stress field. We additional fit to the earthquake migration front (space-time data) three mechanical model of hydroshearing or hydrofracturing. The results indicate hydro-fracturing as the most likely underlying mechanisms driven seismcity. However, we cannot fully rule out hydro-shearing and slip on existing faults. The analysis of this controlled experiment can be a viable tool to better understand fluid circulation in natural geothermal system at volcanoes.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

GEOTERMAC: Strengthening R&D+i capacities for the development of geothermal energy in Macaronesia and São Tomé e Príncipe

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One of the challenges of the European Union is to contribute to promoting the transition towards a safe, sustainable and competitive energy system that will allow reducing dependence on fossil fuels through a significant advance in knowledge about renewable resources. Geothermal energy is one of the least known but most efficient renewable energy sources. The project "Strengthening R&D+i capacities for the development of geothermal energy in Macaronesia and São Tomé e Príncipe – GEOTERMAC; Ref: 1/MAC/2/2.2/0078" has as its main objective to develop methodologies and cooperation tools to strengthen R&D capacities in order to contribute to the energy transition in Macaronesia and São Tomé e Príncipe through the development of geothermal energy. Territorial cooperation becomes a key factor to achieve the project objectives given that these are territories with common characteristics and problems and where geothermal energy is an existing energy resource that needs to be investigated more deeply to evaluate its use as renewable energy. This project is expected to mark a turning point in the progress and efficiency of the current energy system in these regions, thanks to the development of various actions and the application of new and innovative geochemical and geophysical

methodologies to significantly deepen knowledge about the potential geothermal resources existing in the subsoil. The final beneficiaries of this project will be the society of Macaronesia and São Tomé and Príncipe territories.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Surface geothermal exploration by means of soil carbon dioxide and radon degassing in Jedey, La Palma, Canary Islands

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Cost-effective surface geochemical surveys, like measurement of diffuse CO_2 efflux, soil radon (^{222}Rn) and thoron (^{220}Rn) gases activities, have demonstrated to provide relevant information on defining potential geothermal systems boundaries by highlighting permeable areas and potential up-flow zones. A detailed surface geochemical study was carried out in Jedey (25 Km^2), an area of interest for geothermal exploration, located at the west coastline to the western side of the Cumbre Vieja Volcanic Rift Zone in La Palma Island and southwards from the recent lava flows of Tajogaite Volcano. A total of 968 diffuse CO_2 efflux and radon and thoron measurements (~39 sample sites/Km^2) were performed between 2023 and 2024 surveys. Data analysis showed an average CO_2 efflux of 4 $g \cdot m^{-2}$/day, ranging from 0 to 106 $g \cdot m^{-2}$/day, an average ^{222}Rn value of 994 Bq/m^3, ranging from 0 to up to 27,000 Bq/m^3, and an average $^{222}Rn/^{220}Rn$ ratio of 1.5, ranging from 0 to a maximum of 49. Both ^{222}Rn and $^{222}Rn/^{220}Rn$ ratios were plotted together, enabling limiting areas with higher values, which might indicate zones of interest. These variables were used to produce spatial distribution maps showing the main CO_2 and radon gases anomalies along the coastline, but also in some areas following a northeast trend. The CO_2 diffuse degassing might have controlled the migration and transport of the radon trace gas towards the surface. In summary, geochemical surveys have revealed to be a useful technique for surface exploration, allowing identify a potential geothermal system and permitting a posterior subsurface exploration.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

Detailed geochemical study of diffuse degassing in Puerto Naos, La Palma (Canary Islands) for geothermal exploration purposes

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Sustainable exploitation of geothermal resources requires a thorough understanding of the chemical properties of geothermal fluids (water and gases) and the rocks that host their flow paths. Geochemical studies are fundamental to geothermal exploration and development as they provide critical information on the composition, origin and interactions of subsurface fluids and rocks. This information allows the identification of possible geothermal reservoirs, even in the absence of surface manifestations, as was the case in La Palma, Canary Islands until the 2021 eruption. Here are shown the results of an extensive soil gas survey (~5,000 sampling points/km^2) conducted over a 0.11 km^2 area in Puerto Naos, western flank of Cumbre Vieja, La Palma. This area lacks of geothermal surface manifestations. 561 sampling points were selected to measure in situ diffuse CO_2 efflux and ^{222}Rn gas activity. In addition, gas samples from soil atmosphere were collected at a depth of 40 cm for subsequent chemical and isotopic ($\delta^{13}C$-CO_2) analysis. Statistical and spatial analysis of the data reveals significant anomalies indicating gas enrichment from deeper sources. These anomalies may be related to zones of higher vertical permeability and possible potential upwelling or boiling regions at greater depth. The results underscore the relevance of surface gas geochemical studies to delineate subsurface permeability and geothermal potential in areas without surface manifestations, providing valuable data for targeted geothermal exploration and sustainable energy development.

Theme: 5. Geothermal systems and carbon storage

Session 5.1: Unlocking geothermal plays_systems in volcanic settings from cross-disciplinary perspectives

Allocated presentation: Poster

The contradiction between lithospheric thermal and seismic structures reveals a nonsteady thermal state – A case study from Northeast China

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The nature of the lithosphere, as the outermost layer of the solid Earth, has long been a focus of the Earth sciences. Many methods have been used to study the properties and structure of the lithosphere, including gravity, magnetism, electricity, seismic, and geothermics. Since the 1970s, a coupled heat-flow heat-production steady-state model has been employed to study the thermal structure of the continental lithosphere and has helped researchers explain many geothermal observations. However, the steady-state model does not work well in some areas. Taking Northeast China as a case study, we calculated the lithospheric thermal structure, compared the result with seismic research, and concluded that the lithospheric thermal state is nonsteady in the southern Songliao Basin, the southern Greater Xing'an Range and the Changbai Volcano. The lithosphere in southern Songliao Basin features a hot top and a cold bottom. The lithosphere in southern Greater Xing'an Range and the Changbai Volcano feature a cold top and a hot bottom. Our numerical simulation has demonstrated that the response of surface heat flow to thermal disturbance at the bottom of the lithosphere often lags by more than 20 Myr, resulting in a significant disparity between the thermal structure calculated based on surface heat flow and the velocity structure of seismic waves. In addition, this study of the thermal structure in Northeast China shows that the temperature of the Moho in the Songliao Basin is very high (>600°C), which may be an important cause of the lack of Cenozoic volcanism in the Songliao Basin.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Talk [Invited]

Volcanic activity in the Eifel (central Europe) occurred systematically in the millennium before the abrupt North Atlantic warming events of the last 130.000 years - endogenic or exogenic forcing processes?

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The analysis of tephra layers in maar lake sediments of the Eifel shows 14 well-visible tephra layers during the last glacial cycle (0–130,000 BP). These tephra were analyzed for their geochemical and petrographic composition, which allows us to connect several tephra to eruption sites. All tephra were dated by application of the ELSA-23 lake sediment chronology, which covers the entire last glacial cycle in the maar records from Hoher List, Auel, and Holzmaar. Apparently, all 14 tephra were close to interstadial warming events in the Greenland ice and North Atlantic sea surface temperatures. In particular, phreatomagmatic maar eruptions were systematically associated with Heinrich or C-events. The two millennia before the northern warming events represent times of warming of the Southern Hemisphere, global sea level rise and CO_2 increase. The synchroneity within only two millennnia documents a most likely physical relationship between endogenic and exogenic geodynamic processes with climate. Changes in the lithospheric stress field in response to changes in continental ice loads is one potential candidate to explain the connection. Alternatively, a primary forcing from endogenic processes in the upper mantle (heat flow or eruptions under the ice) could be responsible for ice sheet instability. Which of the two processes is indeed the primary forcing cannot be evaluated with confidence. The chronology of volcanic activity in the Eifel in comparison to the chronology of global climate change and northern hemisphere ice sheet decay demonstrates however that intraplate mantle plumes appear to be connected with continental ice sheets and sea level.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Talk [Invited]

Prolonged cold periods in the Holocene due to high-frequency climate forcing

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Understanding climate variability across interannual to centennial timescales is critical, as it encompasses the natural range of climate fluctuations that early human agricultural societies had to adapt to. Deviations from the long-term mean climate are often associated with both societal collapse and periods of prosperity and expansion. Here, we show that contrary to what global paleo-proxy reconstructions suggest, the mid to late-Holocene was not a period of climate stability. Long-lasting cold periods in the Holocene have only recently been detected in local proxies, and not a lot is known about these periods. We use mid- to late-Holocene Earth System Model simulations, forced by state-of-the-art reconstructions of volcanic forcing to show that in the model simulation, eleven long-lasting cold periods occurred in the Northern Hemisphere during the past 8000 years. These periods correlate with enhanced volcanic activity, where the clustering of volcanic eruptions induced a prolonged cooling effect through gradual ocean-sea ice feedback. These findings challenge the prevailing notion of the Holocene as a period characterized by climate stability, as portrayed in multi-proxy climate reconstructions. Instead, our simulations provide an improved representation of amplitude and timing of temperature variations on sub-centennial timescales.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Talk

Why do wet and dry eruptions affect climate differently?

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The two most explosive eruptions of the satellite era resulted in dramatically different effects on Earth's climate.Whereas the subaerial 1991 Mt Pinatubo event was marked by intense stratospheric warming and corresponding surface cooling, the submarine 2022 Hunga Tonga Ha'apai event imparted virtually no significant climate change signal. We explore a hypothesis that key underlying controls are the differing efficiencies of sulfur scavenging by solid ash particles and cloud droplets condensed within eruption columns. Using an updated open-source HYDROVOLC (Rowell et al., 2022) plume model that parametrizes cloud droplet formation and sulfur uptake onto ash and into droplets, we constrain the relative activities of scavenging mechanisms within subaerial and subaqueous explosive eruptions of comparable intensity. We find that subaerial eruptions deliver more stratospheric SO_2 because plume humidity is limited by the availability of atmospheric moisture. By contrast, entrained $textH_2textO^{(v)}$ within subaqueous volcanic jets sustain plume supersaturation, increasing the number and size of entrained droplets that absorb SO_2. We compare our model results to eruptions of observed sulfur injection in the satellite era to find that scavenging microphysics provides a theoretical basis for understanding aspects of the variability of volcanic effects on climate. Our results provide a lookup table for climate models by extending the link between stratospheric sulfur injection and eruptive source conditions to include the effects of volcanic particles as sulfur sinks.In a companion study, we investigate the effects of source water salinity on ash hygroscopicity to distinguish scavenging regimes between freshwater and seawater eruptions.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Talk

Reducing the model simulations – proxy reconstructions discrepancies on the volcanic cooling using reduced complexity models.

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Volcanic eruptions are an important factor of climate variability at annual to multidecadal timescales, but the induced cooling is stronger in climate model simulations than in proxy-based reconstructions. This discrepancy may result from uncertainties in the eruption parameters, the aerosol-climate modelling and natural variability, but the computational cost of complex Earth system models prevents their quantification. Here, we combine a simple aerosol model (EVA_H) and a simple climate model (FaIR). Using ice-core and geological records to constrain SO_2 injection parameters, we generate an ensemble of 1000 simulations for 6755 BCE–1900 CE in which SO_2 injection and model parameters are resampled within their uncertainties. Our simulations reveal that the mean volcanic cooling over the last 9000 years is -0.12 ± 0.04 K, with a maximum yearly cooling of -2.0 ± 0.5 K in 5229 BCE. Critically, our simulations are in excellent agreement with tree ring-based reconstructions of the Northern Hemisphere summer temperature for the 20 largest eruptions of the period 750–1900 CE. This highlights the excellent skill of our modelling approach for estimating the radiative forcing and temperature response to volcanic eruptions. We also explore the suitability of data-driven emulators to simulate the spatial response to volcanic eruption. We adapt several methods of spatial emulation (pattern scaling and machine learning methods) to the climate response (local temperature and precipitation) to volcanic eruptions. The simplicity and versatility of our approach make it accessible to non-expert climate modelers, and ideal to propagate the numerous uncertainties affecting modelling of past eruption impacts.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Talk

Assessing systemic risk response to globally disruptive volcanic eruptions

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Volcanic eruptions pose a systemic risk to our global societies through their ability to disrupt global systems and perturb global climate. Interactions between volcanic hazards and critical infrastructure and systems can trigger a cascade of disruptions and failures in interconnected systems, escalating the impacts to a global scale. In our ever-connected world, even lower magnitude eruptions can have global impacts as demonstrated by the 2010 VEI 4 eruption of Eyjafjallajökull, Iceland which disrupted global transport and supply chains with an estimated cost of US $5 billion to the global economy. The interaction between complex systems and networks and volcanic eruptions is becoming more critical, and this research asks: how prepared are we to respond to the systemic risk from volcanic eruptions? Through interdisciplinary workshops hosted with complexity researchers and with stakeholders across various UN agencies engaged in disaster response and preparedness, this research will share what systemic risk response might look like for a globally disruptive volcanic eruption. Who are the duty bearers responsible for coordinating a response to a systemic volcanic crisis? What resources and funding are required? And what can be done to shift mental mindsets to accommodate better preparedness for large-scale systemic disasters and to move towards transformation in governance systems?

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Talk

The next massive volcano eruption will cause climate chaos — and we are unprepared

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Cataclysmic volcanic eruptions are rare but inevitable. Imagine if the 1815 Tambora eruption happened today? It triggered waves of destructive weather anomalies, cooled the northern hemisphere by 1°C and the subsequent year was said to lack a summer, resulting in meagre harvests. A doubling of grain prices led to societal unrest in Europe and plunged the United States into its first economic depression. The eruption's ripple effects resulted in a death toll likely in the tens of millions. The Tamboran gloom has faded, and the world has been spared from a volcanic eruption of similar magnitude in more than 200 years. Yet, the question is not *if* such a cataclysm will occur again, but *when*. Geological evidence based on volcanic deposits over the past 60,000 years suggests a 1-in-6 probability for a massive eruption to occur in the 21st century. The risks of a Tambora-like eruption within the next five years would cause losses of more than $3.6 trillion, and $1.2 trillion more over subsequent years, due to extreme weather, reduced crop yields and food instability. Those values have large uncertainties attached. To pin down these uncertainties, we call for a three-pronged approach. First, researchers should tie in models and geological evidence for past climates with historic volcanic records. Second, they should explore how volcanic cooling might interact with anthropogenic climate warming. And third, scientists, analysts and policymakers need to design strategies for minimizing the impacts of a catastrophic eruption, by coupling climate, crop and food shock models.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Neglecting future sporadic volcanic eruptions underestimates climate uncertainty

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Most climate projections represent volcanic eruptions as a constant forcing based on historical averages. This constant forcing approach ignores the sporadic nature of eruptions, preventing a full quantification of uncertainties in climate projections. Here we show that the contribution of volcanic forcing uncertainty to the overall uncertainty in global mean surface temperature projections reaches up to 49%, and is comparable or greater than that from internal variability throughout the 21st century. Furthermore, compared to a constant volcanic forcing, employing a stochastic volcanic forcing (i) reduces the probability of exceeding 1.5 ºC warming above pre-industrial level by at least 5% for high climate mitigation scenario (SSP1-1.9) in this century; (ii) enhances the probability of negative decadal temperature trends by up to 8%; and (iii) increases the likelihood of short-term surface cooling and warming events. Intermediate to higher climate mitigation scenarios are particularly sensitive to the choice of volcanic forcing implementation in climate projections. Using a stochastic volcanic forcing approach also enables assessment of the associated climate risks and socio-economic impacts. We recommend improved volcanic forcing approaches for future climate model experiments.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Effects of extreme volcanic eruptions on tree-ring growth in temperate Mexican forests: Dendrochronological evidence.

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Extreme volcanic eruptions, such as Mount Pinatubo eruption of 1991, release millions of tons of sulfur dioxide into the atmosphere. This gas form reflective sulfate aerosols in the stratosphere, causing temporary global cooling by reflecting sunlight back into space. These eruptions can disrupt global climate patterns, leading to extreme weather events such as frosts, droughts, and floods. Although the large-scale effects of volcanic eruptions are well-known, the specific impacts on particular ecosystems, such as low-latitude temperate forests, remain largely unknown. Dendrochronology, by allowing us to analyze tree responses to climatic variations, emerges as a fundamental tool to unravel the effects of volcanic aerosols on these ecosystems and better understand their environmental implications. In this study, dendrochronological techniques were employed to analyze tree-ring series of five conifer species (*Abies religiosa*, *Pinus hartwegii*, *Pinus pseudostrobus*, *Pinus rudis*, and *Pinus oocarpa*) in temperate forests of central and southern Mexico. The results obtained reveal significant disturbances in tree growth, characterized primarily by a decrease in annual ring width. These disturbances are associated with potential historical volcanic eruptions such as Krakatoa (1883), El Chichón (1982), Mount Pinatubo (1991), and Eyjafjallajökull (2010). The disturbances, observed one to three years after each volcanic event, suggest a physiological response of trees to reduced solar radiation and changes in precipitation patterns caused by volcanic aerosols, potentially indicating water stress or reduced photosynthesis. These findings underscore the sensitivity of forest ecosystems to global climatic disturbances and the importance of trees as indicators of environmental change.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Clinopyroxene rim geochemistry: A new tephrochronological tool in maar-lake sediments of the Eifel, Germany.

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Geochemical differences in clinopyroxene rims are utilised as potential differentiators of volcanic eruptions in the Eifel, Germany. This provides the possibility of geochemical tie-points for the tephrochronology of the Eifel Laminated Sediment Archive, i.e. the ELSA-23 chronology and tephra stack. In maar lake sediments of the Eifel with seasonal oxic and anoxic bottom water, volcanic glass fragments are prone to weathering and therefore not always found in sufficient quantities in the lake sediments. To deal with the lack of volcanic glass, we used clinopyroxenes, which are more weathering resistant and present in larger amounts in Eifel eruptions. Only the rims of these clinopyroxenes were analysed, because they represent a geochemical fingerprint closely related to the final magmatic composition prior to the eruption. A total of 13 potential marker tephra of the Eifel Laminated Sediment Archive were analysed with EPMA and LA-ICP-MS. Five of these marker tephra can be uniquely characterised by the geochemistry of clinopyroxene rims. Accordingly, geochemical analysis of clinopyroxene rims represents a promising tool for differentiating tephra and for creating robust stratigraphical tie-points across different archives such as lake sediments and loess, which will be a subject of future studies.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

CO2 budget of Eocene Iranian magmas and their potential contribution to the Middle Eocene Climatic Optimum

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Emissions of CO_2 from magmatic arcs can affect the atmosphere composition, thereby driving long-term global climate changes. Early Cenozoic climate trends are generally associated with changes in global silicate weathering related to Neo-Tethyan geodynamics, but the likely climatic effects of changes in degassing from Neo-Tethyan magmatic arcs have been poorly quantified. Here, we provide the first measures of the volatile content (CO_2, H_2O, F, Cl and S) of pre-eruptive melts based on glassy, bubble-bearing and reheated melt inclusions within plagioclase and clinopyroxene crystals in Early Cenozoic trachyandesites from the Alborz and Tabriz regions (Iran). CO_2 concentrations in these melt inclusions reach up to 6733 ppm, thus providing a minimum estimate of the total amount of CO_2 released from the Iran magmas during the middle-late Eocene of $1.01.10^{19}$ g CO_2, with a total C flux released from those magmas of 0.306 (± 0.123) Mt C/yr. Our findings support earlier hypotheses that magmatic CO_2 degassing from the target igneous provinces played a role in the Middle Eocene Climatic Optimum. Therefore, additional measurements of the volatile contents of Neo-Tethyan magmas are essential to assess the drivers of Early Cenozoic climate trends and to understand the global cycling of volatiles over geological timescales.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

A cluster of major stratospheric eruptions at the end of the Little Ice Age: new insights from polar ice core records

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The final phase of the Little Ice Age, 1800–1850, is the coldest period in the last 500 years and is marked by a cluster of major volcanic events. These include the 1815 eruption of Tambora (Indonesia), the 1835 eruption of Cosegüina (Nicaragua), and two unidentified eruptions in 1808/9 and 1831. Although these events have been linked to climate cooling, major uncertainties remain about the mass and injection height of sulfur and, crucially, the source of the mystery eruptions. Polar ice cores can provide detailed information about historical volcanic emissions. Here, we undertake a high time resolution sulfur isotopic and cryptotephra analysis of the 1800–1850 period. Our results show clear sulfur isotope ($\Delta^{33}S$) anomalies for all volcanic events which indicate stratospheric S injections. 1815 and 1835 show a large time-evolving $\Delta^{33}S$ signal, consistent with a single low-latitude eruption and the known source volcanoes (i.e., Cosegüina and Tambora). For 1831, $\Delta^{33}S$ suggests a Northern Hemisphere eruption and through cryptotephra correlation we are able to link this to a major Plinian eruption of Zavaritskii, a remote nested caldera located in the Kurils (between Japan and Russia). For 1808/9, $\Delta^{33}S$ is more muted and shows a complex time-evolving pattern suggestive of multiple eruptions. Importantly, ice core cryptotephra corroborate this hypothesis and suggest distinct geochemical tephra populations around this time. These data offer exciting insights into the source and style of these major volcanic events and provide essential new input for climate models to examine whether this eruption cluster prolonged the Little Ice Age.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

The compounding climate impact of the 5.6ky BCE eruption of Mount Mazama

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The Mount Mazama (Crater Lake, U.S.A.) eruption counts among the largest eruptions of the Holocene, yet its impact on contemporaneous climate, environment, and humans remains uncertain. Here, we use Earth System Model simulations to provide an improved understanding of the potential impacts of this cataclysmic eruption on global climate, and we relate this to societal impacts. The model simulations produce severe and diverging temperature and precipitation anomalies in different regions of the world. We argue that the compound occurrences of severe cooling and precipitation extremes likely had a significant impact on the agrarian, pastoralist, and foraging societies living in these regions, with crop failures due to drought and pronounced flooding in areas with extreme precipitation increase. Our study illustrates how large volcanic eruptions can alter surface climate, with varying and contrasting compound climate anomalies covering much of the land surface. A volcanic event like the Mount Mazama eruption while rare can also occur in the next decades or centuries. In the present, an eruption of this magnitude has considerable potential for multiple critical infrastructure and breadbasket failures, impacting food security, lives, and livelihoods around the world. Studying these very large past eruptions is thus imperative for better understanding the nature of and risks associated with low-likelihood, high-impact events – events that global society is patently ill-prepared for.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Evolution of volcanic eruptions with environmental change at Katla and Eyjafjallajökull volcanoes

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The effect of climate-induced environmental change on eruptive style at glaciated volcanoes is poorly understood. Most studies of subglacial or ice-marginal volcanic eruptions focus on monogenetic volcanoes or individual eruptions where the environmental conditions are considered constant. Polygenetic volcanoes, however, erupt over millennial timescales and have the potential to record eruptive behaviour throughout climatic and environmental change. We present a new geological map of a >50-kyr sequence of volcanic products exposed in the dissected flanks of Katla and Eyjafjallajökull volcanoes. We use known stratigraphic markers, the Þórsmörk ignimbrite and Vedde-composition pumices to constrain the time interval of eruptions. Additionally, $^{40}Ar/^{39}Ar$ and paleomagnetic dating of lavas provide a more detailed chronology of eruptions and environmental change. The sequence consists of hyaloclastite-lava sheets, hyalotuffs, intrusions, pillow lavas, breccias and ice-confined lava flows. The variety of products reflects eruptions beneath a fluctuating ice sheet with temporal variations in meltwater accumulation. Subaerial lavas and ignimbrites indicate glacial cover was punctuated by locally ice-free conditions. The penultimate eruptive phase exposed is a lava delta that prograded into an englacial lake, coincident with retreat of the Icelandic Ice Sheet. In addition, glacial outburst floods associated with eruptions in a destabilising ice sheet helped to incise deep valleys that expose the sequence. We propose that climate-induced environmental change influenced eruption styles at Katla and Eyjafjallajökull. Given the ongoing reduction of glaciers at ice-capped volcanoes, it is critical to better understand how eruptive behaviour might evolve with changing glacial and hydrological conditions.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Unprecedented growth of volcanic aerosols in vorticized volcanic plume parts from 2019 Raikoke eruption (Kuril Islands)

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The 2019 stratospheric eruption of Raikoke volcano had major impact on atmospheric composition and climate. The exact composition of Raikoke particles is still debated, especially in the long-lived, compact and vorticized plume parts, where ash and sulfate fractions are uncertain. The microphysical properties of volcanic particles, especially their size, are poorly known, whereas crucial for understanding their lifecycle and constraining climate models. The synergistic analysis of satellite (S5P/TROPOMI, MetOp/IASI) observations with ground-based photometric measurements (AERONET network) allowed us to provide novel information on particle sizes for aerosol typing. As shown recently for Hunga Tonga stratospheric particles (Boichu et al. 2023), when a plume overpasses a station, aerosol volume size distributions reflect a third mode that can be attributed to volcanic particles. In the vorticized plume parts, fine particle peak radii are shown to grow to 0.8-1 microns three months after the eruption. This is approximately thrice the size reached by the growing particles in the other non-vorticised plumes dispersed in the Northern hemisphere. Such different patterns support the growth of sulfate aerosols, which is heightened in the compact vorticised parts, likely resulting from increasing nucleation and coagulation in highly concentrated parcels. CALIOP data show a self-lofting of the vorticized plume parts from 14 km to 26 km in three months, with depolarization ratios decreasing from > 0.25 to < 0.01. High depolarizing properties that are rapidly lost may indicate the initial presence of fine ash particles rapidly coated by sulfate.

Boichu et al 2023, DOI: 10.1029/2023JD039010

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Historical stratospheric aerosol optical properties and volcanic sulfur emissions for the next generation of climate models

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Stratospheric aerosols, most of which originate from explosive volcanic sulfur emissions into the stratosphere, are a key natural driver of climate variability. They are thus one of the forcings provided by the Coupled Model Intercomparison Project (CMIP) Climate Forcings Task Team for the CMIP7 Fast Track, a set of climate model experiments designed to deliver the Intergovernmental Panel on Climate Change (IPCC) 7th assessment cycle. In this work, we document the final version of the historical (1750-2023) stratospheric aerosol forcing datasets delivered to modelling groups for CMIP7 Fast Track. We produced one volcanic stratospheric sulfur emission dataset catering for the needs of models which have a prognostic interactive stratospheric aerosol scheme, as well as a stratospheric sulfate aerosol optical property dataset required by models that cannot interactively simulate stratospheric sufate aerosols. For the satellite era (from 1979 onwards), sulfur emissions and sufate aerosol optical properties are based on the MSVOLSO2L4 and GloSSAC datasets, respectively. For the pre-satellite era (1750-1978), the emission dataset is based on ice-core datasets complemented by the geological record for small-moderate magnitude eruptions not captured in ice-core records. Although inferring emissions of these eruptions from the geological record is highly uncertain, our approach minimizes an important bias in the pre-satellite era forcing, both in terms of mean and variability. The pre-satellite aerosol optical property dataset is directly derived from emissions using an updated version of EVA_H, a reduced-complexity volcanic aerosol

model. We will discuss the role of the volcanology community in improving these datasets in the future.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Pumice and Ash

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Juvenile pyroclasts produced by explosive eruptions vary in size, density and internal textures (bubble and crystal population). Petrologists analyze lapilli-sized clasts to assess magma storage conditions and volcanologists use lapilli to measure both density and the vesicle population. The ash fraction, however, is often ignored, despite representing the bulk of many deposits. Here we demonstrate that the ash fraction provides a complementary part of the story, including insight into both pre-eruptive magma staging within the conduit and syn-eruptive fragmentation. Here we compare the morphologies and internal textures of pyroclasts that range in size from lapilli (8 mm) to ash particles (125 mm) from pre-climactic and climactic deposits of the ~7.7 ka Mount Mazama eruption (Crater Lake, Oregon). Preliminary results show that ash fractions have lower vesicularities than measured in pumice lapilli. Additionally, the ash fraction of precursor deposits appears to have lower vesicularity than ash produced during the climactic phase. Precursor deposits also show a wide range in bubble shape and size as well as in groundmass microlite content. Together, these data provide evidence of pulsatory onset to the climactic eruptive activity.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Societal Responses and Impacts from Volcano-Induced Climate Shocks

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Volcanic eruptions pose multi-hazard risks, including tephra fallout, pyroclastic flows, tsunamis, and global climate shocks. While these primary hazards can be modelled with reasonable accuracy, cascading second- and third-order impacts are less understood. These depend on global exposure, pre-existing vulnerabilities, and human decision-making, which can mitigate or exacerbate outcomes. Historical records show that while some societies faced decline under comparable conditions, others adapted through mechanisms such as trade networks, highlighting the importance of governance and socio-economic resilience in the severity of the impacts. Using historical case studies climate shocks following eruptions in 1815, 1783, 1600, 1257, 536/540, and 43 BCE, we identify four recurring pathway cascades: famine, economic hardship, disease outbreaks, and political/civil instability. We break down the various mechanisms behind each pathway, which have been influenced by societal resilience and responses. For instance, repeated human responses such as hoarding, profiteering, trade disruptions, and exploitation of weakened states demonstrate the pivotal role of human agency in shaping cascading impacts. We will evaluate how these historical pathways could manifest in a modern volcanic climate shock. In today's interconnected world, such shocks would cascade through governance, trade, and food systems, compounding other global risks like anthropogenic climate change and political instability. Historical responses demonstrate that resilience—through trade, innovation, and effective governance—can mitigate some of the environmental shocks. By integrating historical insights, we aim to strengthen global risk frameworks and inform strategies, such as prioritising resilience-building and addressing structural inequalities, on vulnerable populations and regions to mitigate future volcanic climate shocks.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

What if? Quantifying exposure to high-impact low-probability eruptions

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Due to their rarity and high mitigation costs, large-magnitude volcanic eruptions are often overlooked in disaster risk analysis and management in favour of more plausible events. However, population growth, technology dependency, and increased global system complexity would result in catastrophic impacts of such an eruption on a hemispherical to global scale. Identifying the potential scale and locations of hazards and impacts from large-magnitude volcanic events can help focus future research and target collaborative preparation efforts. Assessing exposure and potential impacts from these high-impact, low-probability events is challenging due to the lack of past event data, which makes forecasting difficult and introduces large uncertainties. Furthermore, to date, global exposure analysis methodologies typically consider distances up to 100 km from a volcano, even though past VEI 7 eruptions have deposited tephra beyond this distance. In this research, we propose a methodology to assess exposure to these large-scale eruptions. We assess exposure of populations, buildings, and infrastructure around likely candidate volcanoes for potential VEI 7 eruptions, with particular attention to those near waterbodies where tsunamis are likely to be triggered and those in tropical latitudes, which may have global climate implications. Using tephra fall isopachs from case studies of past VEI 7 eruptions, we calculate the probabilities of current and future exposure to tephra fall based on prevailing wind direction. We emphasise the sensitivity of tephra fall exposure to wind direction and isopach extent. Due to the high cross-border exposure, we highlight the need for international collaboration in preparing for such high-impact, low-probability events.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Six million years long Bayesian chronology of VEI 7+ eruptions recorded by a tephra sequence on the Detroit Seamount, NW Pacific

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Explosive eruptions are among the most dangerous natural disasters. They are rare and highly irregular in time. Long continuous records of eruptions are needed to elucidate the temporal structure and driving forces of explosive volcanism. In the NW Pacific, the longest eruption records come from tephra sequences of the three cores on the Detroit Seamount, ~700 km downwind of Kamchatka (Ocean Drilling Project Sites 882 and 884 and WEPAMA core MD01-2416). These cores had well-developed age-depth models, which we were able to merge into a single Bayesian age model through geochemical fingerprinting and correlation of tephra layers. A total of 119 tephras recording VEI 7+ eruptions over the last 6.2 Ma have been identified and dated to an accuracy of better than 70 ka (median error 7.5 ka). Fractal analysis of ash-falls timeline indicates a multiscale grouping (correlation dimension Dc = 0.74) with no dominating frequencies. Even for the last 700 ka, a period of the most pronounced glaciations, Milankovitch cycles are indiscernible in the power spectrum of ash-falls timeline. Of the total 119 tephras, each individual core contains sixty-five or fewer, indicating that the combination of several closely spaced cores is needed to provide a more complete record of ashfalls in the area. Evident incompleteness of individual tephra records raises a question of signal interference between the volcanism itself and ash transport and deposition. The research was supported by the Russian Science Foundation grant #22-17-00074.

Theme: 6. Hazard, Risk and Impact

Session 6.1: Volcanic impacts on climate and societies

Allocated presentation: Poster

Patterns of Plio-Pleistocene Ice Volume Variability Recorded by the Large-Magnitude Explosive Eruptions from the Kamchatka-Kurile Volcanic Arc

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Marine fallout ash beds can provide continuous, time-precise records of highly explosive arc volcanism that can be linked with the climate record. To investigate for causal links between climate evolution and volcanism during the past four million years, we compiled new and existing data of marine ash beds at ODP Sites 881, 882, and 884 to obtain a time-precise and temporally highly resolved record of the Plio-Pleistocene (0 to 4 Myr) Kamchatka-Kurile arc volcanism. The tephrostratigraphies confirm the cyclicity of the Kamchatka-Kurile arc volcanism and its marked increase at 2.73 Ma just after the intensification of the Northern Hemisphere glaciation. The stacked tephra record reveals periodic peaks in arc volcanicity at ~0.3, ~ 1.0, ~1.6, ~2.5, and ~3.8 Myr that coincide with maxima of the global ice volume variability that have been linked with the amplitude modulation of the precession (0.3, 1.0 Myr) and obliquity (1.6, 2.5 and 3.8 Myr) bands. A model of a decreasing obliquity variance across the mid-Pleistocene Transition at constant precession variance produces an excellent correlation of ash bed cycles with the variability of global benthic $\delta^{18}O$ ($r^2 = 0.75$). Collectively, the data imply external modulation of the Kamchatka-Kurile arc volcanism which is not direct orbital forcing but the climate-controlled periodic waxing and waning of the large ice shields that influence the frequency of mantle melting. However, the Kamchatka-Kurile arc volcanism may still influence climate by feedback.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Talk

Seawater interaction and degassing process of magma during the 2022-2023 eruptions at Ioto volcano, Ogasawara, Japan: Implications for hazard assessment of shallow sea eruption

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Submarine eruptions ubiquitously occur across diverse depths and locations on Earth, causing significant volcanic hazards. In shallow seas, continuous magma-water interaction is thought to control eruption intensity. While it is well known that open-system degassing of magma plays a key role in controlling eruptive intensity by limiting gas expansion in magmas. Understanding shallow sea eruptions thus requires integrating magma-water interaction with degassing processes to better assess eruption hazards. This study investigates the 2022-2023 shallow sea eruption off Ioto Island, Ogasawara, Japan, to illuminate these processes. The eruption, observed in shallow sea (10–20 m depth) with intermittent cock's tail jets, deposited pumice along the southern coast of the island and produced pumice raft that reached southwestern Japan. Petrological analyses reveal chilled margins of pumice, with vesicularity of 20–40 vol.% and a water content of ~0.21 wt.%, suggesting rapid cooling near the seafloor (<0.2 MPa). Thermodynamic modeling and water content of melt inclusions in phenocrysts indicate magma storage at 970 °C with water content of 1.3 wt.%. The water budget and vesicularity of magma indicate that open-system degassing occurred during the eruption. These findings suggest that the eruption was driven by ascent of magma which underwent open-system degassing, followed by seawater interaction near the seafloor, triggering rapid cooling and fragmentation. Boiled seawater and residual gas in magma likely fueled cock's tail jets. By integrating magma-water interaction and degassing processes, this study suggests monitoring of volcanic gas derived from the open-system degassing is important for hazard assessment of shallow sea eruption.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Talk

Imaging magmatically induced tectonics at the East Pacific Rise 9º50'N

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Mid-ocean ridges, the longest volcanic chain that wraps around the globe in ~60,000 km, represent a natural laboratory to examine genetic relationships between the tectonic and magmatic processes and provide linkages between surface and subsurface observations at metric scales. Several submarine focus sites with well-developed magmatic systems, such as the East Pacific Rise (EPR) 9º50'N, are extensively studied. At this fast-spread center, faults within the axial summit trough (AST) are induced by vertically propagating dikes from the underlying magma body. Beyond the axial high (>2000 m), the formation of the faults is associated with the unbending of the lithosphere. A handful of inward-dipping faults are mapped between these thermally distinct zones, but their origin is poorly understood. This study uses an interdisciplinary approach, comparing unprecedented ultra-high-resolution 3-D seismic imagery and bathymetry data collected at the EPR. Our findings reveal a remarkable alignment between the distinct morphological features of magma bodies and steeply dipping faults. By directly comparing the architecture of a shallow emplaced magma body away from the AST and the geometry of the associated fault, we propose the mechanism for the fault unzipping; furthermore, we directly measure thermal anomaly along the fault and present the first images of potential magma pathways. The evident spatial link between tectonic and magmatic expressions in datasets and asymmetric fault nucleation mode argue for the most direct evidence for magmatically induced faulting, providing pathways for magma emplacement and hydrothermalism, with the lessons learned potentially transferrable to the volcanic systems operating on land.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Talk

Evidence for a Hydrothermal Event in Santorini's Caldera Preceding a Large Volcanic Eruption

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Santorini is a mature volcanic system located in the South Aegean volcanic arc. Though its eruptive history is well-studied, the post-caldera evolution of the volcanic and hydrothermal systems remains poorly understood. Our objective is to understand the relationship between volcanic eruptions and hydrothermal activity within the caldera. This study focuses on the chemical analysis of samples from seafloor sediment cores collected from the Santorini caldera during International Ocean Discovery Program (IODP) Expedition 398 in 2023. Samples from four sites (U1594-U1597), which penetrated between depths 45 and 130 meters below the sea floor (mbsf), were selected to obtain a comprehensive record of volcanic and sedimentary activity since the last caldera-forming eruption 3600 years ago. The sediment record is hypothesized to include both subaerial and submarine eruptive products from the young, intra-caldera edifice (Kameni Islands) that has progressively grown. The aim of our study is to detect past episodes of hydrothermal activity by examining trace metal enrichment patterns in accumulating sediments. Our hypothesis is that sedimentary units show enrichments in elements that are typically elevated in hydrothermal fluids, indicating heightened activity. We present results for down-core concentrations of strongly enriched elements, in particular Hg, Sb, Mo and Mn, where a key horizon between 55 and 60mbsf shows particularly elevated concentrations of these elements—consistent with a period of strong hydrothermal activity prior to a large eruption of Kameni in 726 CE. We draw comparisons with the present-day hydrothermal fields, and explore ways to constrain the extent and significance of this ancient hydrothermal event.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Talk

Surface phenomena and hazards of explosive submarine eruptions revealed by a global dataset

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Submarine volcanic eruptions often produce diverse surface phenomena and hazards that differ from those of eruptions on land, such as phreatomagmatic explosions, tsunamis, and pumice rafts. Understanding the causes and processes of these surface phenomena and hazards posed especially by large-scale explosive submarine eruptions is essential for disaster prevention and mitigation for marine volcanoes. Herein, the surface phenomena and processes of explosive submarine eruptions in recent years are summarized. Analysis of recent eruptions is useful to elucidate key phenomena and processes during submarine eruptions and to evaluate the types and effects of hazards. I constructed a global database focusing on submarine eruptions and extracted their general characteristics. I focus on the relationship between the water depth and the occurrence of surface phenomena, such as explosivity, subaerial pyroclastic density currents (PDCs), and tsunamis. Database analysis showed that the number of explosive phenomena on the sea surface and tsunamis decreases dramatically at depths ≥ 400 m, and that detection methods are almost entirely limited to underwater sound waves, pumice rafts, discolored water, and direct observation by expeditions. The proportion of eruptions accompanied by PDCs over the sea surface is less than 11% of the total, although eruptions in shallow water are more likely to be accompanied by PDCs. The database analysis strengths our knowledge of hazardous phenomena such as phreatomagmatic explosions, high eruption plumes, and tsunamis, and also contributes to constraining possible phenomena during historical eruptions and assessing future hazards at submarine volcanoes.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Talk

Nature of offshore Hunga eruption deposits and behaviour of subaqueous volcaniclastic density currents

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Explosive volcanism frequently occurs in marine settings where erupted pyroclastic material can enter the ocean and generate powerful subaqueous volcaniclastic density currents (SVDCs). The capacity for these density-driven currents to travel hundreds of kilometres across the seafloor and damage critical subsea infrastructure poses direct threats to remote island communities. These threats were highlighted by the January 15th, 2022, eruption of the shallow-submarine Hunga volcano, Kingdom of Tonga, where eruption triggered SVDCs damaged subsea telecommunication cables, severing Tonga from global communication. Despite their hazardous nature, understanding of density current behaviour and their seafloor impacts has been limited by a paucity of real-time observations and minimal in-situ deposits categorically linked to these currents. We address this knowledge gap with the first detailed sedimentological and geochemical characterization of the deposits of SVDCs triggered during the 2022 Hunga eruption. Using the submarine sedimentary record of this event we characterize these SVDCs and their resultant depositional signature. We show that periodic eruption-column collapse triggered multiple pulses of density-stratified currents that ran-out >117 km. Erosion and entrainment of ~3.5 km^3 of material into the currents increased flow mobility, speed, and competency, enabling them to deposit coarse material 105 km from source. Through integration of well-observed subaerial eruption phenomena and post-eruption bathymetric data we contextualize the density currents within the eruption timeline. Identification of these SVDCs coupled, here, with detailed deposit characterization provides step-changes for understanding the destructive and distributive processes dispersing volcaniclastic

materials across the seafloor, and the threats posed to vulnerable communities and infrastructure.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Talk

Comparing hydrothermal responses to eruption on submarine arc volcanoes and mid-ocean ridges.

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More than 300 submarine hydrothermal systems have been located and sampled, but there are very few direct observations of hydrothermal activity associated with deep submarine eruptions. Hydrothermal fluids produced by interaction of erupting lava, hot magmatic gases, and seawater have been sampled at NW Rota-1, a basaltic volcano on the Mariana arc, and at West Mata, a boninite volcano in the NE Lau basin. The chemistry of fluids sampled directly over erupting lavas from both sites (pH 1 to 2, high levels of dissolved SO_2, Mg concentrations higher than seawater, elevated levels of Fe, Al, and Si, low Li) indicate rapid and short duration acidic attack on freshly erupted lavas by condensed, SO_2-rich magmatic gases mixed with seawater. These fluids are unlike the high-temperature fluids produced in the deep subseafloor (near zero Mg, pH 3 to 5, elevated trace alkalies), where conditions approach equilibrium at low water/rock ratios. High-temperature fluids collected on or near freshly erupted basalt in 1991 on the East Pacific Rise have low Mg, low Cl, high H_2S, slightly enriched Li, and other characteristics associated with high-temperature reaction of limited duration plus phase separation (Von Damm, 2000). Differences between the hydrothermal response to eruptions on MOR and submarine arc volcanoes can be tentatively attributed to the structure of hydrothermal circulation around dike-driven eruptions with existing high-temperature vents on MORs versus conduit-fed eruptions within more permeable constructional volcanic cones on arcs. Magma redox state also plays a role, producing SO_2-rich fluids on arcs and H_2S-rich fluids on MORs.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

Geochemical and Sm-Nd Isotopic Data of the Tachdamt and Bleida Formations (Bou-Azzer, Anti-Atlas, Morocco): Evidence for Two Sep-arate LIPs on the NW Margin of the West African Craton During the Early Neoproterozoic

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This study presents new geochemical and Sm-Nd isotopic data from the mafic rocks of the Tachdamt and Bleida formations in the Bou Azzer inlier, Anti-Atlas, Morocco. These formations, once considered a single sequence, have been redefined by U/Pb zircon dating into two distinct units: the Bleida Formation (770–700 Ma) and the Tachdamt Formation (c. 883 Ma). Our aim is to assess the origin and geodynamic significance of these rocks based on updated geochronology. The Tachdamt Formation, characterized by flood basalts, marks the onset of Tonian rifting along the northern edge of the West African Craton. In contrast, the Bleida Formation is interpreted as an arc-related terrane along the Anti-Atlas margin. Both formations contain mafic rocks, mainly basalts, and dolerites, showing tholeiitic signatures typical of passive margins. Light rare earth element (LREE) patterns suggest an E-MORB-type mantle source, with some samples showing enrichments in heavy rare earth and large ion lithophile elements, possibly indicating a distinct magmatic episode. Neodymium isotopes reveal positive εNd(t) values, indicating a juvenile magma source. Depleted Mantle model ages for the Bleida Formation are grouped into three ranges: 2080, 1600, and 1244 Ma, while the Tachdamt Formation ranges from 1990 to 1710 Ma. The εNd(t) vs. SiO_2 plot suggests minimal crustal contamination. This study reveals two separate magmatic events in the area, but geochemical and isotopic similarities point to a common mantle source, shedding light on the region's complex Neoproterozoic magmatism.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

Geochemistry of a Neoarchean hot subduction volcanic suite discovered beneath the Cretaceous Deccan Traps, India

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Arc as well as plume magmatism has sub equally contributed to the growth of continental crust on the Earth, since the Archean era. Unlike the crust that is exposed and accessible on the surface, the nature of the crust concealed beneath the volcanic igneous provinces such as Siberia and Deccan have remained enigmatic. Apparently, the voluminous lava pile deters access to the concealed basement, unless retrieved through deep continental drilling. Unlike the Siberian traps, the depth of lava in the Deccan does not exceed 1300 m, and therefore, penetrable through the underlying crust. CSIR-NGRI has drilled four scientific deep bore-holes (KBH-5, 8, 9 and 10) that penetrate the granitic basement to a depth of 1500 m. The volume of the basalt lava extracted from these well-cores extends to a depth of 1200 m. In comparison to the rest, KBH-5 is unique, in the sense that in this region the Deccan Traps are underlain by a Neoarchean (~2.58 Ga) volcanic sequence of ~300 m thick at -400 m m.s.l., instead of granites. This succession comprises of a hot subduction volcanic suite of rocks. The extension of this suite is traceable beyond 300 km on the surface, south of the Deccan Traps. This study provides first physical evidence and new information on the arc volcanic rocks of the Dharwar Supergroup extending further beneath the Deccan Traps. Unveiling of potentially similar scenarios entrapped beneath the vast canopy of continental flood basalts, would reveal new crustal growth events during Precambrian-Phanerozoic transition across the Earth.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

The threat of volcanic tsunami from Whakaari/White Island to the Bay of Plenty, New Zealand.

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Near shore volcanoes pose difficulties to quantify threats to nearby coastlines from a variety of tsunami generation mechanisms. Here we focus on flank collapse induced tsunami from Whakaari/White Island, New Zealand, and its impact on the Bay of Plenty coast. We characterise the island through multi-physics geophysical inversion and clustering algorithms to identify saturated and hydrothermally altered rock volumes that are mechanically weak. From these models we identify clusters of potential slope failures with differing characteristic safety factors and failure volumes. Several areas are identified on the northwest and southwest flanks, and range in volume from 10^5 to 10^8 m^3. Characteristic volumes of rock are defined and used as sources for landslide stability models that feed into a widely used tsunami simulation code - COMCOT (Cornell Multi-grid Coupled Tsunami) for coupled landslide-tsunami simulations. We adapted COMCOT specifically to handle debris flows typical of edifice failures so that we can fully couple the subaerial and submarine dynamics. This involves a flexible nested grid algorithm that allows for two-way coupling of landslide-tsunami simulations to address differences in spatial resolution requirements and model coverages between landslide and tsunami simulations. We model the tsunami wave height and inundation at the Bay of Plenty coast, about 50+ km distant and find that tsunami generated by flank collapse are highly directional yet can attain heights that create land threats for affected areas. This work forms the basis of the first volcanic-sourced tsunami assessment for near shore New Zealand volcanoes.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

Volcanic evolution of the Bathymetrists Seamounts (equatorial Atlantic) since the Paleocene

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The Bathymetrists Seamounts (BSM) are an elongated intra-plate volcanic province in the equatorial Eastern Atlantic Ocean. They are situated north of the Sierra Leone Rise, a smooth, aseismic seafloor elevation, believed to have formed above a hot spot at the Mid Atlantic Ridge. The arrangement of the 40 elongated seamounts, some of which are over 100 km long, is enigmatic. The strike direction of the seamounts is either parallel to the intersecting fracture and transcurrent zones or tilted by about 30° to 60°, which has been interpreted as evidence of Riedel shears. Previous age models are based on the geochemistry of a few dredged (surface) rock samples. With the first set of ca. 4000 km of high-resolution multichannel seismic reflection data, we provide new insights into the structural and temporal evolution of the BSMs. Subsurface images reveal stacked seamount structures, offering direct evidence for their relative order of formation. Based on the DSDP site 366 findings, we establish a chrono-stratigraphic model for the sediment basins between the seamounts. This allows us to approximate the age of the underlying volcanic flanks and to refine the spatial and temporal evolution of BSM edifices through the Paleocene to Eocene. Furthermore, our data reveal signs of recent hydrothermal and magmatic activity, including intrusions, mud diapirism, and fluid chimneys penetrating the volcanic flanks. These findings highlight the BSMs as a dynamic system with both ancient origins and ongoing activity, offering new perspectives on understudied intra-plate volcanism and its associated processes.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

Deep sea volcaniclastic deposits at the foot of Walvis Ridge seamounts (South Atlantic) and Ulleungdo Island (East Sea/Sea of Japan) reveal complex subaqueous to subaerial explosive volcanism in intraplate settings

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Volcaniclastic deposits at the foot of large intraplate oceanic volcanoes are commonly associated with erosion and reworking of volcanic products from shallow-marine to subaerial environments and can also be a direct product of subaerial explosive volcanism. However, primary volcaniclastic deposits resulting from subaqueous explosive volcanism could also occur in deeper marine environments, but there remains very limited evidence for them. New lithological and geochemical observations stemming from rotary coring of the lower flanks of Walvis Ridge seamounts during IODP Expedition 391 and piston coring of the seafloor close to Ulleungdo Island and Anyongbok seamount in the East Sea (Sea of Japan) document varied modes of subaerial to subaqueous volcanic activity. On the flank of Walvis Ridge seamounts, Upper Cretaceous to Palaeocene primary volcanogenic turbidites were encountered interbedded with lavas close to 4 km water depth. These deposits were emplaced during the island stage of the seamounts and document coeval effusive and explosive volcanism in both subaerial and deeper marine conditions. In the East Sea, Quaternary pumiceous mass transport deposits and tephra layers found below 2 km water depth reveal important tephra reworking on the flank of Ulleungdo Island during Plinian eruptions and, probably, recurring regional dispersals of pumice rafts. Geochemical and tephrochonological constraints suggest subaqueous pumice formation close to 500 m water depth at Anyongbok seamount. Together, new deep-sea observations from the South Atlantic and the East Sea outline complex subaerial to subaqueous volcanic processes and effects in intraplate settings, with yet unclear tsunamogenic implications.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

Submarine mass-wasting and volcanism on the flanks of Ulleungdo Island and Anyongbok Seamount in the East Sea of Korea

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Mass-wasting and submarine volcanic events on the lower flanks of seamounts and islands are important for understanding submarine geohazards associated with the evolution of large intra-oceanic volcanoes. These events were studied in the East Sea of Korea using new piston cores from the foot of Anyongbok Seamount and Ulleungdo Island. At the Anyongbok Seamount, numerous ca. 1 to 20 cm-thick pumiceous lapilli to breccia layers were found interbedded with background pelagic sediments. New petrographic and geochemical analyses of volcanic glass in these layers and other tephra in the region support their formation by local, subaqueous volcanic eruptions (<500 meters below sea level), with no or limited post-depositional reworking. In contrast, a ca. 2.65 m-thick, normally graded layer of pumiceous breccia to lapilli was cored at the foot of Ulleungdo Island. Mud clasts and compositional heterogeneity of the pumices towards the base of the deposit indicate reworking by gravity flow along the island's slope. This is consistent with chirp seismic profiles that show transparent seismic facies and locally hummocky topography - features diagnostics of Mass Transport Deposits (MTDs). Volcanic glass composition in the MTD and other tephra layers in the East Sea and Japan suggest that the pumiceous MTD at Ulleungdo Island correlate to U-Ym (or SKP-I) Plinian eruption at ~40 ka. This indicates that large subaerial eruptions can produce submarine MTDs associated with regional tephra fallout and/or pumice rafts. This is the first evidence for volcanogenic deep-sea MTDs and explosive volcanism at an island and seamount in the East Sea.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

The architecture of explosive deep-water volcanoes in the Azores Plateau

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In deep-sea settings, lava fragmentation is generally thought to result from quenching rather than explosive eruptions due to magmatic volatile pressure. However, several studies provide evidence of explosive submarine eruptions at significant water depths. Geophysical evidence remains sparse though. In this study, we use high-resolution seismic reflection data to reconstruct the polygenetic development of deep-water volcanoes on the Azores Plateau. The studied volcanoes have formed along the southern diffuse plate boundary of the Azores Plateau, which is characterized by dextral transtensional movement. Around 10 million years ago, explosive eruptions led to the formation of a few kilometer-wide diatremes within pelagic sediments. Subsequently, intraplate lavas flooded presumably more than 10.000 km^2 of the plateau, and shield volcano like edifices filled craters on the surface of the diatremes in paleo water depths beneath 2.2 km. After a non-volcanic phase of approximately 5 million years, a second volcanic phase began with explosive eruptions above the diatremes, displacing the intervening pelagic sediments over several kilometers. By the end of this volcanic phase, a volcanic edifice about 400 meters high with a crater approximately 500 meters wide had formed. The crater was filled with effusively erupted lava by the end of the volcanic activity. The present-day volcanic edifices are 4–4.5 km wide and 500–550 meters high. This study underscores the significance of reflection seismic data for studying underwater volcanoes, as it provides the critical insights needed to infer explosive underwater eruptions, which bathymetric data alone cannot offer.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

The Sandy Bay caldera-forming silicic submarine eruption at Macauley volcano, Kermadec arc/Rangitāhua

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Macauley volcano is a submarine silicic composite volcano in the Kermadec intra-oceanic arc/Rangitāhua, north of New Zealand/Aotearoa. The volcano comprises an extensive shallow-water edifice punctured by a large submarine caldera and the small remnant of an island. The submarine slope of the volcano includes eruption-fed, giant sediment waves and older submarine landslides. The up to 100 m high cliffs on Macauley Island form the Sandy Bay Tephra (SBT), which geochemically match the submarine sediment waves and distal marine tephra, and attest of a voluminous pumice-forming silicic eruption associated with the current submarine caldera. Based on a comprehensive set of sediment core and onland samples, augmented by 14C geochronology and bathymetry and seismic reflection data, we reconstructed the eruption stratigraphy to infer vent environment and eruption and transport processes that acted during this major event. The interpreted eruption behavior of the Sandy Bay eruption is compared to other submarine caldera-forming eruptions, notably the much smaller 2022 Hunga Tonga eruption, to assess hazards linked with such end-member eruption style.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

Far-travelled ash megaturbidite fed by shoreline-crossing pyroclastic currents from the Kos Plateau Tuff eruption. IODP Expedition 398, Hellenic Arc Volcanic Field

Tim Druitt*[1], Abigail Metcalfe[1], Katharina Pank[2], Steffen Kutterolf[2], Jonas Preine[3], Karim Kelfoun[1], Christian Hübscher[4], Paraskevi Nomikou[5], Thomas Ronge[6], and IODP Expedition 398 scientists.

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Explosive eruptions from island volcanoes deliver huge quantities of ash to the marine environment. While many of the transport pathways are understood, those from shoreline-crossing or submarine pyroclastic currents, and the water-supported gravity flows into which they transform, are not. We report the discovery during IODP Expedition 398, of an ash megaturbidite up to 200 m thick buried deep in the rift basins of the South Aegean Volcanic Arc. The 80 cubic km of ash derives from the 161 thousand-year-old Kos Plateau Tuff (KPT) caldera-forming eruption 120 km to the east, as shown by offshore-onshore chemical correlation of glasses and minerals. The marine ash forms a chemically homogeneous graded bed that lacks internal bioturbation. This implies an emplacement time of less than the several months to years typically required for seabed re-population by burrowing organisms. We propose that the ash bed sedimented from a stream of eruption-fed turbidity currents that travelled westwards 120 km from the Kos eruptive center down arc-parallel slopes to the rift basins. These basins at the time were deep bathymetric troughs that captured the Kos-derived turbidity currents, allowing great thicknesses of ash to accumulate far from the eruption source. The megaturbidite increases the total erupted volume of the KPT eruption to >200 cubic km (uncompacted), suggesting that eruption volumes for other island or coastal explosive eruptions may also be underestimated. The study highlights how large volcanic eruptions re-mould sea floor landscapes, lay down ash megabeds, and destroy seafloor biota on island-arc-wide scales in short-lived, catastrophic events.

Theme: 6. Hazard, Risk and Impact

Session 6.2: Deep to emergent marine volcanism: Hazards and processes from the seafloor to the sea surface

Allocated presentation: Poster

Spatio-temporal framework of Mayotte's submarine volcanism based on new K-Ar ages.

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In May 2018, a major seismo-volcanic crisis began east of Mayotte (North Mozambique Channel) leading to the eruption of a new submarine volcano, named “Fani Maoré”, ~50 km off Mayotte at the eastern end of the submarine Eastern Mayotte Volcanic Chain (EMVC). This chain, oriented N110°E to N130°E, consists of monogenetic pyroclastic cones, lava domes and lava flow fields identified from high-resolution bathymetric data. This chain includes a remarkable horseshoe-shaped morphological structure, 10 km offshore Petite-Terre Island, associated with seismic swarms and liquid CO_2 venting. The present study aims at providing a time frame for construction of the submarine edifices of the EMVC, in particular of the Horseshoe volcanic complex. Samples from volcanic cones and lava flows were collected during 9 oceanographic campaigns using dredging and the Victor6000 remotely operated vehicle (ROV). In total, 28 samples, from basanites to phonolites, were dated using the K-Ar method on carefully selected glassy groundmass. Our new ages range from 3.74 ± 0.04 Ma to 3 ± 1 ka. Five ages, all from monogenetic cones, are over one million years, three of them located north of the EMVC along a N40°E alignment. Most of the young ages come from the Horseshoe area, confirming that this volcanic complex was formed recently and may still be active. Together with previously published ages, our new ages suggest regional periods of volcanism and quiescence throughout the Comoros Archipelago, which could be linked to distinct phases of tectonic activity occurring during the last 1 Ma in this key area.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Talk [Invited]

Assessing long-term volcanic gas hazard through probabilistic approach: insights from case studies

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Persistent volcanic degassing can have significant long-term impacts (years to decades) on both human health and the environment at local and regional scales. To address these risks, probabilistic volcanic hazard assessment (PVHA) of gas dispersion has recently emerged as a critical tool for risk mitigation in active volcanic areas. Standard PVHA methodologies rely on running physical models of gas dispersal that explore uncertainties in input parameters and boundary conditions, enabling robust hazard quantification. However, model validation is crucial to ensure accuracy before applying such tools in probabilistic frameworks. Uncertainties in volcanic gas hazard assessments arise from simplifications in the physical processes and assumptions in model formulations. This contribution shows some numerical performances aimed to provide realistic long-term assessments of gas concentrations at active volcanic sites characterized by persistent passive/gravitative degassing such as La Solfatara crater (Campi Flegrei, Italy), Vulcano (Aeolian islands, Italy) Caldeiras da Ribeira Grande (São Miguel Island, Azores), Stephanos crater (Nisyros, Greece), Lake Pavin (France). Using published and original flux data, probabilistic numerical simulations were carried out using the open-source Python workflow VIGIL for parallelized probabilistic outputs. Simulations incorporate two Eulerian models (DISGAS and TWODEE-2), accounting for passive and gravity-driven gas transport, respectively. The probabilistic hazard results incorporate meteorological variability over the past 30 years, derived from Copernicus ERA5 reanalysis data. This approach provides critical insights into potential gas hazard scenarios and their implications during future periods of volcanic unrest, contributing to effective hazard preparedness and mitigation strategies.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Talk [Invited]

Many Maps are Better Than One: A Random Forest Approach to Estimate Spatial Density in a Distributed Volcanic Field, Eastern Snake River Plain (ID)

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Machine learning offers a powerful approach for estimating the probable location of new volcanic vents. We employ a Random Forest machine learning algorithm that objectively combines multiple statistical models of spatial density with multiple geophysical models across a common area within a distributed volcanic field (DVF). This approach uses a variance weighting scheme to create composite spatial density estimates that directly incorporate relevant geophysical observations with statistical models for the probability of the opening of new vents. The approach is applied and tested in the eastern Snake River Plain (ESRP), Idaho, where 617 Quaternary vents are mapped along the path of the Yellowstone hotspot track. Six spatial density models are applied to this dataset: three kernel density estimators and three adaptive estimators. Four geophysical models and measurements are included as predictor variables: (1) long-wavelength topography, (2) a strain model for a block representing the ESRP lithosphere, (3) an ESRP gravity model, and (4) an ESRP aeromagnetic model. Composite Random Forest spatial density estimates are created using the multiple spatial density and geophysical data grids. A composite spatial density estimate for the opening of new vents is then applied to a tephra fallout hazard assessment for various facilities located within the Idaho National Laboratory on the ESRP. This approach could be used as an alternative to expert judgment when weighting alternative spatial density models for probabilistic volcanic hazard assessments.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Talk

Estimating proximal hazards in a distributed volcanic field

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Assessing volcanic hazards in distributed volcanic fields (DVFs) is complicated by their dispersed vents (spatial uncertainty), long irregular repose periods (temporal uncertainty) and diverse eruption styles (hazard uncertainty). The Probabilistic Volcanic Hazards Assessment of Idaho National Laboratory (INL) USA developed an approach to assess proximal hazards where the location and style of eruption are uncertain. In contrast to most volcanic hazards assessments, in which likely vent areas are known and hazard zones are then mapped, the sites for which the hazards assessment is needed are defined and the vent locations, timing, and style of eruption are not initially defined. The hazard assessment is split into distal (fallout and flows from distant volcanic areas; hazards vary little across INL) and proximal hazards. To develop the proximal hazards assessment, a hazard footprint for each type of volcano (low shield, scoria cone, spatter cone, dome, cryptodome, phreatomagmatic vent) was created. The hazards associated with each volcano type and their extent from a vent were determined, using ESRP and analog examples. Hazards include burial, ballistic projectiles, gas, pyroclastic currents of various types, and ground deformation. For each eruption style, the areal extent of each hazard was estimated and a combined footprint created using the probability-distance relations for all hazards, producing a circle or oval having generally decreasing probabilities with distance from vent. These footprints are centered on the sites of interest rather than vents. The spatio-temporal likelihood of future eruptions within the footprints was then evaluated to assess hazard probability at each site.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Talk

Lava Flow Hazard Assessment for Flagstaff and Surrounding Areas in the San Francisco Volcanic Field (Arizona, U.S.A.)

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The San Francisco Volcanic Field (SFVF) in northern Arizona (USA) contains over 600 basaltic cinder cones, along with several larger volcanic structures. The most recent eruption, at Sunset Crater in ~1085 CE, impacted the local Sinagua population and is remembered in Native American oral traditions. Flagstaff, with a population exceeding 76,000, is the largest urban area within the SFVF. Given Flagstaff's rapid population growth, assessing lava flow hazards from future eruptions is essential. In this study, we identify 585 basaltic vents from satellite imagery and categorize them into three age groups based on magnetic chronologies. We characterize 30 lava flows using field observations and digital elevation models (DEMs) to estimate their size and extent. In combination with estimates of the spatial probability of future vent opening, these data are used to simulate lava flow inundation probabilities using the MrLavaLoba and MOLASSES models, with median flow areas of 7.5 km^2 and volumes of 0.24 km^3. Our results suggest a low probability (~few percent) of lava flows reaching Flagstaff, with some vents potentially located within city limits. However, the probability of lava inundation in residential areas northeast of Flagstaff, such as Doney Park, is higher, potentially affecting over 5,000 residents. With an eruptive recurrence interval of ~1 per 10,000 years, lava flow hazards to Flagstaff are low but should be considered in urban planning.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Talk

Probabilistic tsunami hazard assessment at Stromboli volcano (Italy)

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Volcanic-induced tsunamis have a potentially devastating impact, especially in densely populated and/or touristic coastal areas. Stromboli volcano (Aeolian islands, southern Italy) is known for its persistent explosive activity occasionally punctuated by more powerful explosions and lava effusions. Most of the erupted products tend to accumulate within the "Sciara del Fuoco" area, a horseshoe-shaped subaerial and submarine depression located to the NW of the island. The high amount of unstable material within such area has led to the development of tsunamigenic landslides, from low volumes (< 1 Mm^3) resulting in negligible tsunami waves and inundation, up to larger volumes (≥30 Mm^3) producing high-amplitude tsunami waves and large inundation. In this study we present a probabilistic tsunami hazard assessment for Stromboli Island that includes: i) a review of historic tsunamis at Stromboli and their correlation with explosive/effusive activity; ii) a dataset of inundation maps from simulations of tsunamis generated by landslides along the Sciara del Fuoco; iii) an uncertainty quantification analysis through expert elicitation of several aspects of tsunamigenic landslide at Stromboli (e.g., their number in the past and in the next 50 years, the probabilities of different triggering mechanisms, the relative probability of different volumes and initial positions of the tsunamigenic landslides). Results consist of probabilistic inundation maps and hazard curves in different locations of the island coupled with a temporal model of occurrence valid for the next 50 years. Maps are presented with a specific focus on the village of Stromboli and accounting for the quantified uncertainty.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Talk

Beyond the eruption: a holistic approach to understanding cascading hazards and risks at Stromboli.

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This study investigates tsunamigenic mass flows at Stromboli volcano, focusing on the complex interactions between volcanic activity, coastal hazards, and the related risks. Using the two fluids version of the VolcFlow model (https://lmv.uca.fr/volcflow/), we conducted numerical simulations of past events, particularly the July 3, 2019 eruption, to understand the dynamics of pyroclastic density currents (PDCs) entering the sea and their tsunami-generating potential. Our parametric study reveals that PDC volume and discharge rates are critical factors in tsunami generation, with wave height increasing with volume and decreasing with lower discharge rates. High-resolution bathymetric surveys and digital elevation models provided crucial input for refining our models, highlighting the importance of regular and advanced subaerial and submarine surveys to increase the accuracy of forward modelling. Once we have studied these processes, we have introduced an impact chain analysis to broaden our understanding of hazard interrelationships, potential impacts, vulnerabilities, and mitigation measures. The study emphasizes the importance of interdisciplinary approaches in volcanic risk management, combining advanced numerical modeling, continuous monitoring, and impact analysis in the case of Stromboli and with implications for similar hazard-prone areas worldwide. Interdisciplinarity, where geological, engineering, environmental, and social perspectives are integrated, contributes to improving hazard assessments, early warning systems, and risk reduction strategies for volcanic coastal environments both in research and risk management. By combining these diverse disciplines, we can develop more comprehensive and effective strategies for mitigating risks and enhancing community resilience in volcanic regions.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Talk

Monitoring long-term deformation of coastal volcanoes in Southeast Asia with Sentinel-1 InSAR

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Deformation of volcanoes and their flanks is a ubiquitous process at many volcanoes worldwide but presents a major concern due to the potential of flank instabilities and collapse. This is particularly relevant for volcanoes near the coast as such a collapse into the sea could trigger a far-reaching tsunami. We collected multi-year Sentinel-1 InSAR data to investigate surface deformation of 18 near-sea volcanoes in Southeast Asia with the aim to identify potential flank instability and tsunamigenic potential. We further correlate this with the volcanic activity measured by the volcanic radiative power (VRP) and reported periods of unrest or eruptions. We find that over 80% of the studied volcanoes exhibit signs of persistent or episodic surface deformation, in most cases expressed as Line-of-Sight (LOS) increase reflecting subsidence and/or slope movement with large variability in spatial extent and displacement rates, ranging from mm/yr to dm/yr. In multiple cases, subsidence is likely associated with gravitational processes that imply flank instability. We highlight likely ongoing flank instability at Anak Krakatau and Ulawun, and present results for multiple other volcanoes showing potential signs of gravity-driven movements, though data coverage is often insufficient to be conclusive. Additionally, we identify multiple cases where deformation rates appeared to accelerate in direct response to increased volcanic activity or eruptions and remaining elevated for several years after. This data offers key insights into the spatio-temporal scales of volcano deformation in Southeast Asia and reveals a direct link to eruptive activity, which may facilitate flank instability and potential collapse hazards.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Towards the probabilistic construction of eruptive scenarios of the El Chichón volcano (Mexico): advances in ash dispersion modeling.

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El Chichón volcano, located in southern Mexico, gained worldwide recognition after its catastrophic eruption in 1982 (VEI 5), which resulted in over 2,000 fatalities and the displacement of several villages. Since then, numerous studies have been conducted to understand the dynamic processes of this volcano. For instance, the actual hazard map was constructed using a deterministic approach, considering only the most recent eruption as a scenario. However, it is necessary to adopt a probabilistic approach to comprehend better and define eruptive scenarios, considering the stratigraphic records available for the last 10,000 years. A probabilistic approach is needed to account for volcanic processes' inherent uncertainties, providing a more comprehensive and realistic view of potential eruptive scenarios. To achieve this, modern tools must be employed to simulate various volcanic processes, thereby generating various possible outcomes based on statistical analyses. This includes variations in eruptive parameters, atmospheric conditions, topographic influences, etc. In this study, we present the preliminary results in ash dispersion modeling, utilizing the latest version of **FALL3D** and incorporating data from different atmospheric levels using global and mesoscale models (ERA-5 and WRF) and variation in eruptive parameters considering the Holocene stratigraphic record. These results will contribute to developing a new probabilistic hazard map for the El Chichón volcano, including other processes such as pyroclastic density currents and syn and post-eruptive lahars.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Temporal recurrence rate estimation in distributed volcanic fields

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A critical element in hazard estimation from distributed volcanic fields, particularly in regulatory environments, is the estimation of temporal recurrence. The low temporal frequency of distributed volcanism means the historical record is commonly nonexistent or inadequate, and interpretation of the geological record is required. However, the geological record is incomplete, uncertain, and in multiple forms, subject to a variety of constraints. A holistic view of the temporal record can be assembled by generating age realizations via Monte Carlo simulation. Each realization is a random draw from all of the data available, where all of the constraints, such as stratigraphy, are satisfied, in contrast to their average, where constraints may be violated. We illustrate how Monte Carlo simulation can provide a basis for temporal recurrence estimates, including aleatory and epistemic uncertainty, using the example record of Quaternary volcanism in the eastern Snake River Plain. This consists of 617 vents, 156 with isotopic dates, 307 with paleomagnetic determinations, and 2644 stratigraphic relations. In addition, undated vents and their mapped lava fields have been subjectively assigned to age groups (0–200 ka, 200–400 ka, 400–780 ka, 780–2000 ka) based on their geomorphic features, paleomagnetic data, and stratigraphic relations relative to dated map units in contact. Age realizations are simulated from these with and without applying the age groups. After disaggregating the record to derive homogeneous ‘regions’ in space and/or composition, various temporal models can be fit to these realizations, providing estimates of recurrence rates with quantified uncertainty.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Forecasting Future Eruptions using Hierarchical Trend Renewal Processes

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Forecasting volcanic eruptions can be challenging due to the typically sparse and incomplete data available in geological and/or historical eruption records. This leads to analysis of volcanoes with comparable physical properties and statistical behaviour (eruption recurrence) to a target volcano. Analogue patterns are thus used to estimate model parameters and forecast future eruptions. This approach, however, often fails to consider the specific problem of *missing data*, which is common due to the uncertain and possibly unknowable processes in geologic records over thousands to tens of thousands of years. To approach this problem, we propose a set of hierarchical trend renewal processes to model analogue volcanoes to account for missing data. From these we create a Bayesian model averaging scheme for forecasting. This incorporates model uncertainty by combining the posterior distribution of the forecast times from each of the considered models. We apply this method to forecasting eruptions from Mt Taranaki in New Zealand, which last erupted in ~1780 AD and has its entire eruption record only preserved in geological deposits.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Bringing Together Scientific and Community Knowledge to Improve Assessment of Lahar Impacts in St. Vincent

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The 2020 – 21 eruption of La Soufrière, St. Vincent expelled substantial volcanic debris on its flanks. During heavy rainfall events, these are remobilised as lahars, posing serious threat to infrastructure and communities. While patterns of occurrence have changed since the eruption, lahars remain a significant hazard, so up-to-date hazard maps on lahar model predictions are crucial. Using the dynamic model LaharFlow (www.laharflow.bris.ac.uk/), we present new predictions of damage to roads and bridges, as well as to offshore communication cables by estimating fluxes of sediment and water transported to the ocean during lahar events. We also assess the consequences of engineered mitigation strategies, such as recent boulder-lining of certain northeastern river channels. Through rainfall analysis, combined with simplified catchment hydrology, and lahar observations, we present a new approach for scenario selection for lahar hazard mapping, and new model estimates of lahar arrival times. Simulated lahar depths and speeds align well with flow observations on the coastal areas of St. Vincent. Most of the lahar observations were provided by the ‘Changing Landscapes’ project, which supported communities in the northeast of St. Vincent to document changes after the 2021 eruption. These observations are critical for understanding how lahars have changed since the 2021 eruption. Initial meetings with the National Emergency Management Organisation (NEMO) and National Met Services have identified a pathway for using these community observations and model results in national hazard mapping, and we discuss the benefits to both communities and government agencies of bringing this knowledge together.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Strain and fault evolution during gravitational volcano collapse: experiments with different substrata geometries

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Many volcanoes on Earth show evidence of gravitational collapse of their entire structure or a sector, at rates ranging from slow spreading and sagging of a few millimetres to centimetres per year to catastrophic collapse. While deformation at the surface of volcanoes can be observed using geodetic methods, its relation to structures inside the volcanic edifice and below, i.e. basement geometries is not systematically explored. This study uses analogue models composed of a ductile layer (the detachment) overlaid by a brittle layer (the basement) with different slope geometries and a cohesive conical edifice (the volcano) to experimentally investigate how the geometry of a volcano's basement controls surface deformation under gravitational loading. Therefore, we vary systematically the angle of an implemented basement slope, and the distance between a fixed slope and the volcano. We observe generally lower deformation rates with decreasing basement slope angle and increasing distance between volcano and slope. Transtensional faults develop mainly on the part of the edifice facing the basement slope. Grabens narrow from the peak toward the edifice base. The faults are activated in a stick-slip manner, with a decrease in activity frequency with time. From the strain field analysis, we see compressional structures at the summit, which are more likely activated after extensional deformation in the lower part of the edifice. Based on these new models, we discuss how the fault pattern on the analogue volcanic edifice and fault activation with time are perturbed by the basement parameters, i.e. slope inclination or distance to slope.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Long-term probabilistic volcanic hazard assessment on islands: the case of tephra fallout at São Miguel airport (Azores archipelago)

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Volcanic islands face unique challenges when affected by explosive eruptions due to their limited land area, typical rough topography, and the concentration of populated areas and infrastructure close to volcanic centres. Moreover, eruption records of island volcanoes are often incomplete or poorly preserved, generating large uncertainties in their eruptive behaviour and in constraining eruption source parameters. This study presents a long-term probabilistic volcanic hazard assessment (PVHA) methodology applied to a volcanic island, specifically focusing on the airport of São Miguel Island (137,000 inhabitants) as a case study. It aims to evaluate the potential impacts of tephra fallout on airport operations and infrastructure, providing the probability of different tephra loads impacting this critical infrastructure over specific time windows. To perform this analysis, different sources of information were integrated, including the probability of an explosive trachytic eruption at each of the three central volcanoes on the island, as well as the likely locations to host future vents. Probabilistic simulations of tephra deposition were conducted for different eruption scenarios accounting for wind variability. Bayesian Event Trees were constructed for each volcano to produce hazard curves to quantify tephra load exceedance probabilities at the airport location, and probability maps showing the exceedance probability of specific tephra load thresholds. This approach represents a methodology for volcanic hazard assessment on islands, suitable for application to other volcanic regions facing similar challenges as the Azores, thus supporting effective risk management and enhancing community resilience.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Energy line approaches in a level set framework for probabilistic modelling of volcanic surges

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Energy line approaches are often used to delineate pyroclastic surge extent, favoured in PVHA for their computational speed and simple input parameters. However, outputs are limited to inundation extent, do not account for flow channelisation or cross-axis flow, and input parameters that can be difficult to relate to physical characteristics of the eruption. The difficulty is to account for these factors while not compromising on computational time. Here, we have reformulated energy-based approaches in a level-set framework. This formulation iteratively defines the frontal position of the surge using a propagation function, which enables new advancements to energy line approaches such as channelisation, dependence on mass discharge rate and settling velocity, flow redirection (e.g. 'tree-branching') and potentially extraction of hazard intensity functions. The framework utilises graphics processing units, meaning the computational cost of this reformulation is negligible, and allows for large sample spaces necessary in PVHA. The new approach is demonstrated in an application to the Auckland volcanic field, an application with varying vent locations and eruption sizes. This application took 10 hours to complete for 5,000 simulations, and supported the extraction of surge hazard in terms of extent and intensity. We show the results of this application, validations against New Zealand surges and demonstrate some potential extensions using this framework to account for different energy approaches (e.g. energy conoid), flow redirection, and discuss the suitability of extracting a hazard intensity measure from the level set framework.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

To what degree can we forecast volcanic ballistic projectile hazard?

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Volcanic ballistic projectiles (VBPs) are the most common cause of fatality for both tourists and scientists on volcanoes. Quick and easy to use probabilistic forecasts could provide information on where VBP would most likely impact, how intense the impact will be and subsequently the ability to calculate risk to life to exposed people. Here we present results from an exploratory data analysis of 152 collated VBP hazard values, investigating relationships between factors that may be used to forecast hazard. Data was analysed from 77 different volcanoes, with over 50% of those values from mafic volcanoes (composition), stratovolcanoes (morphology), and from Strombolian eruptions (eruption style). Hazard characteristics with enough data to analyse for relationships included maximum clast size, maximum travel distance and maximum velocity. We see a strong positive correlation between VBP maximum velocity and maximum travel distance and can see some explanatory value when the data is split into different eruption styles. We found that eruption style is a significant factor affecting maximum travel distance, though the presence of a hydrothermal system, volcano composition, volcano morphology type, individual volcano, were not found to be significant factors affecting the three characteristics analysed. This means that eruption style, if it can be forecast, could be used to forecast the distance to which VBPs may impact.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Probabilistic volcanic hazard assessment during quiescence: A scenario-based framework for Gede, West Java (Indonesia)

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Assessing areas likely to be affected by volcanic hazards is one of the first steps towards reducing volcanic risk. This assessment often utilises analysis of a volcano's past eruptions to forecast the size and style of future eruptions and the spatial extent of the hazards. However, there are many active volcanoes that do not have extensive eruption records to forecast future behaviours from, Gede volcano is one example. We conducted the first probabilistic multi-hazard assessment for Gede, the closest active volcano to Jakarta, Indonesia's largest city. To supplement Gede's limited eruption record we used analogue volcanoes and global datasets to develop eruption scenarios, and to parameterise hazard models. Our analysis suggests that major and Plinian explosive eruptions could deposit sufficient tephra to disrupt airport operations and vital lifelines across the city of Jakarta, while tephra fall from prolonged eruption scenarios may obscure road markings and disrupt agriculture operations proximal to the volcano. Flow hazards are primarily impact the northeastern flank of the volcano; lava flows reach ~3 km in this direction, block-and-ash flows are expected to extend up to ~11 km, and dilute pyroclastic density currents from a collapsing minor explosive eruption column can extend up to ~15 km. Through this work we have provided a background probabilistic hazard assessment for Gede volcano and a framework for volcanic hazard assessment in data-limited contexts. This assessment serves as a tool for preparedness and planning for the future eruptions, enhancing risk mitigation in one of the most exposed regions of the world.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Impact of tsunamis generated by landslides at Stromboli on the entire Aeolian Island chain

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At Stromboli (Aeolian Islands, Italy) tsunamis can be generated by landslides and pyroclastic density currents entering the sea. The proximity of the other Aeolian Islands (Panarea, Salina, Lipari, Vulcano, Filicudi and Alicudi), which are mostly within 20-50 km of Stromboli, results in high exposure to the tsunami hazard at all islands. In December 2002, tsunamis were generated by two landslides at Stromboli and impacted mostly Stromboli itself, but also all Aeolian Islands as well as the northern coast of Sicily. The first tsunami reached the closest neighbour island, Panarea, just 5 minutes after the first landslide. Numerical simulations of tsunamigenic landslides on the unstable NE flank of Stromboli (i.e., the Sciara del Fuoco) were run to define inundation area scenarios along all Aeolian Island coastlines. Each combination of landslide parameters (position, volume and density) gave us three outputs: coastal inundation (flooding extent and flow depths), offshore wave heights, and tsunami arrival times. In addition, virtual gauges were placed around the Aeolian islands to measure maximum sea heights and associated arrival times. In the case of tsunamis generated by a local source, i.e., where tsunami travel time is <10 minutes, evacuation routes must be defined in advance and signposted on the ground. Currently, except for Stromboli, no signposting is yet in place in the Aeolian islands, hence the importance of our joint work with the Italian civil protection. These studies are crucial for civil protection planning, in terms of scenario building and adoption of risk reduction measures by the local authorities.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Insights into the Colli Albani caldera: current ground deformation and susceptibility to debris flows analysis

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Colli Albani (Italy) is an active caldera with seismic swarms, ground deformations and gas emissions located mainly in the southwestern part of the volcanic district, where the last phreatomagmatic expressions arisen about 27 ka ago. Moreover, several types of landslides, among which the most common are debris flows, affect frequently the volcanic complex. Therefore, the volcanic risk is not negligible. This contribution aims to display the results obtained within the INGV funded SIMCA project in terms of ground deformation and debris flow susceptibility. The former were obtained through the application of a multi-temporal SAR Interferometry technique exploiting Cosmo-SkyMed and Sentinel-1 data, acquired from 2016 to 2023. Results were validated using GNSS measurements allowing identify that the only signal that could be related to volcanic activity is the 1.5 mm/yr uplift, confined to the southwestern part of the caldera, at the Genzano di Roma municipality. The uplift rate appears to be smaller than that found out in previous works, suggesting no magma emplacement within the crust at least during recent years. In addition, the debris flows susceptibility of the volcanic complex was obtained through a heuristic approach combining morphometry elements, lithology and land cover, parameters recognized as the main predisposing factors to slope instability. The resulting susceptibility map, validated through historical landslides, classifies the entire complex according to five degrees of susceptibility, identifying Tuscolano-Artemisio caldera edge, Mt. Faete, and steep slopes of Nemi and Albano lakes at high and very high susceptibility.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

DispAtlas: A flexible tool for the automated construction of seasonal dispersal pathways and exposure of volcanic emissions

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The significant impact of volcanic emissions on atmospheric composition and climate has highlighted the need for comprehensive monitoring of volcanic emissions from active volcanoes worldwide. Protection of human health requires better knowledge of local and regional characteristics of volcanic plume dispersal. This study addresses the issue of transport dynamics of volcanic emissions by developing an automated algorithm to study the seasonality of common dispersal pathways from major degassing volcanoes; here applied to volcanoes covered by the NOVAC (Network for Observation of Volcanic and Atmospheric Change) network, as captured in the CAMS Volcano database. For each volcano, ERA5 reanalysis data were used to drive the FLEXPART lagrangian transport model to simulate the dispersion of volcanic plumes from passive degassing. A quasi-realistic reduction of volcanic emissions amounts in the FLEXPART model was achieved by applying an exponential first order decay, based on representative lifetime calculations accounting for both gas-phase oxidation and deposition processes. Pathways were identified using the k-means clustering algorithm, which led to robust groupings that reflect climatological and topographic phenomena and exhibit strong seasonality. Finally, the potential exposure to volcanic emissions was estimated using population density data from the Global Human Settlement Layer (GHSL). While this study focuses on NOVAC network volcanoes, the methodology can easily be extended to additional volcanic systems and can be used to carry out hypothetical studies to aid in hazard assessment and emergency response planning for regions with significant volcanic activity.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Rapid detection of faults and fractures using drone magnetometry: Insights from the Grindavík hazard zone, Reykjanes Peninsula, Iceland

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The renewed tectonic and volcanic activity in Reykjanes Peninsula also resulted in significant faulting, fracturing, and graben formation in the town of Grindavík in November 2023 and January 2024. This posed risk to infrastructure and public safety, particularly through the formation of sinkholes, subsidence, and surface instability. Effective mitigation of this activity required rapid and accurate mapping of the structures in the subsurface. Drone-based magnetometry provides a novel possibility for detecting and characterizing subsurface faults, sinkholes and fractures. By measuring magnetic anomalies caused by contrasts between nonmagnetic features, such as sinkholes and fractures, and highly magnetic basaltic lavas, this technique can efficiently map hazardous areas, even in challenging terrain. This study highlights the application of drone magnetometry in the Grindavík hazard zone. By integrating magnetometry with complementary datasets such as InSAR and DEMs, we provided insights into the fault and fracture systems associated with the graben formation. The results demonstrate the method's usefulness in rapid-response scenarios, which are essential for informed hazard assessments, decision making, and risk mitigation in tectonically active regions.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Monitoring of carbon dioxide hazard in the inhabited areas of Puerto Naos and La Bombilla, La Palma, Canary Islands

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The eruption of the Tajogaite volcano in 2021, Cumbre Vieja (La Palma, Canary Islands) is the eruption with the greatest impact on urban areas in Europe during the last 75 years. Once the eruption was over, the main volcanic risk that has been present until now is the anomalous emission of CO_2 affecting the inhabited areas of Puerto Naos and La Bombilla, both 6km from eruptive vents. The first records of high levels of open-air CO_2 concentration in these areas were measured by INVOLCAN approximately three weeks before the end of the Tajogaite eruption (December 13, 2021). To investigate this volcanic hazard, regular studies of diffuse CO_2 emission have been conducted at La Bombilla, whereas outdoor and indoor air CO_2 concentration have been monitored regularly at La Bombilla and Puerto Naos since December 2021. Diffuse CO_2 emissions at La Bombilla have shown values from 4.0 to 170 td^{-1} (average=14.4 td^{-1}) with $\delta^{13}C$-CO_2 values ranging from -8.63 to -4.28‰ vs. VPDB (average=-5.5‰). Temporal evolution of diffuse CO_2 emission rate showed maximum value during first study (170 t d^{-1}), with rest ranging from 4.0 to 70 td^{-1}. CO_2 concentration in outside air measured at a height of 15cm at La Bombilla and Puerto Naos showed values up to 87% (average=0.67%) and 30% (average=0.23%), respectively, the highest recorded so far during the post-eruptive period. Both inhabited areas must be continuously monitored to reduce the risk associated with gas emissions, and innovative decisions are currently being considered to mitigate the danger associated with CO_2.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Long-term continuous monitoring of diffuse CO2 emission from the summit cone of Teide volcano, Canary Islands, Spain

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Tenerife Island (2,034 km^2), the largest of the Canary Islands, is characterized by three volcanic rifts zones: NSRZ, NERZ and NWRZ, and a central caldera hosting the Teide-Pico Viejo volcanic complex. With the aim of strengthening volcanic monitoring and providing a multidisciplinary approach to the monitoring of the Teide volcano, a continuous monitoring of diffuse CO_2 emissions was implemented. To do so, a geochemical station was installed at the base of the summit cone in 1999 following the accumulation chamber method to record the continuous diffuse CO_2 efflux. It also records meteorological and soil physical parameters. Measurements are made on an hourly basis 24 hours a day. The 1999-2024 time series show strong variations of the diffuse CO_2 efflux values ranging between 0 (non-detectable) and 62.8 $kg \cdot m^{-2} \cdot d^{-1}$, with a mean value of 4.88 $kg \cdot m^{-2} \cdot d^{-1}$. To define the relations between CO_2 efflux and environmental variables and to use these relations to filter out the effects of environmental variables on the measured CO_2 efflux time series, a MRA filtering was performed. From middle 2001 a significant increase of seismic activity was recorded, especially during 2004, characterized both by an increase in the number of small earthquakes, mostly along the NWRZ and along the southern part of the NWRZ. We interpreted these signals as "early warning" associated to the 2004 volcanic unrest. A similar behavior was observed for the periods 2006-2009, 2014-2016 and 2020-2022, always followed by an increase in the local seismicity at Tenerife and the occurrence of seismic swarms.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

ALERTACO2 Project: Update of an extensive monitoring network for monitor and mitigate the CO2 hazard of indoor and outdoor air CO2 at the inhabited areas of Puerto Naos and La Bombilla, La Palma (Canary Islands)

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During Tajogaite eruption in 2021, anomalous CO_2 degassing appeared affecting the neighborhoods of La Bombilla and Puerto Naos, both about 6 km southwestern from the volcanic vent. These urban areas, not directly damaged by lava flows, were included in the exclusion zone due to the strong volcanic-hydrothermal CO_2 concentrations (>5-20%). CO_2 is an invisible toxic gas, as well as asphyxiant gas, and may be lethal when it is present in concentrations > 14V%. During the post-eruptive period, several institutions deployed own gas networks to delimitate CO_2 anomalies, but their number was insufficient (<100). The results of these studies and the appearance of dead fauna (insects, birds, lizards and small mammals) due to high CO_2 concentrations and low O_2 levels in the air has made it necessary to install more CO_2 stations in real-time, in order to delimitate the CO_2 anomalies where CO_2 air concentration exceed that hazardous thresholds, and help the authorities decision-making of people's return to their homes and stores. The ALERTACO2 project, participated by IGN and INVOLCAN institutes, was financed by the Spanish Government with an amount of 3M€, and has the goal of installing around 1,200 sensors in real-time, sending the data to a 24-hour monitoring room. At the present time, 1294 sensors are installed (1,287 indoor and 7 outdoor), of which 147 are in La Bombilla and 1,133 in Puerto Naos and 7 moving stations and 7 outside these places. Thanks to ALERTACO2, many families have been able to return in safety conditions to their homes.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

A new insight into secondary volcanic hazards at Stromboli: the case of Gravity Induced Flows of 3rd July 2019 paroxysm by high resolution topographies from satellite data

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Among the secondary hazards generated by eruptive events, gravity-induced flows (GIF) are particularly significant due to their rapid onset and destructive potential. Such phenomena, were observed during the 3rd July 2019 paroxysm at Stromboli Island (Aeolian archipelago, Italy). One of the two GIF affected the island western flank involving the summit hiking path. To reproduce such flow, a new procedure that generates Digital Surface Model by using NASA's Ames Stereo Pipeline platform and models the flow dynamics was developed. First results were obtained by using numerical codes based on rheology models that allow to represent the flow behavior. Here this approach provides new insights into the volcanic hazard assessment.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Searching for unrest patterns at central volcanoes exploiting monitoring data from 1980 to 1999

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In order to forecast eruptions, it is essential to better understand unrest and determine whether this leads to eruption (eruptive unrest) or not (non-eruptive unrest). Here we contribute to this problem by studying the monitoring behaviors of central volcanoes experiencing eruptive or non-eruptive unrest. We created an original database of episodes of unrest at central volcanoes occurred between 1980 and 1999. We analysed the database in search of common and recurrent patterns among unrest types and across different volcanoes. Our analysis shows that volcanoes with mafic magma or open conduit tend to erupt more frequently. Eruptive unrest is usually characterized by volcano inflation, opening of fractures and increase in degassing, whereas deflation and stable degassing are common features for non-eruptive unrest. There is a weak relationship between the time of two subsequent eruptions and the size of the second eruption, especially for eruptions having VEI ≥4. Eruptive unrest episodes are shorter (usually lasting <2 years) than non-eruptive ones (which may last up to 5 years). The shorter duration of episodes of unrest preceding eruptions supports previous models, suggesting that magma may only be erupted for a limited period of 1-2 years before being stored in the upper crust. The similar features of unrest at calderas, derived from previous studies, suggest that pre-eruptive dynamics is independent of the presence of a central conduit.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Wildfire mapping triggered by volcanic activity: impact on Stromboli Island during the 2019 summer by using Remote Sensing Data

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Active volcanic environments, such as Stromboli (Aeolian Islands, Italy), are often affected by secondary hazardous phenomena as wildfires triggered by explosive activity. Such secondary hazard are able to cause damages in the surrounding human settlements, cultivation and huge losses of vegetation. This study identifies and maps the burnt areas during the 2019 summer explosive activity. Between 2nd July and 5th September, two paroxysms, along with intense explosive activity, caused extensive wildfires, affecting vegetation and the inhabited Ginostra village. Landsat-8, Sentinel-2, and Pléiades satellite data have been processed to calculate the spectral indexes NDVI and NBR. Such index identified burnt areas making the difference of NDVI and NBR maps between pre- and post- paroxysm (3rd July). The 3 maps of burnt areas obtained by satellite data were compared with the burnt areas mapped by using a very high spatial resolution drone imagery. Fire-outbreaks were also detected between 4th July and 5th September, due to the high explosive activity during such period and due to the second paroxysm occurred on 28th August. As Stromboli is a popular tourist destination, this study offers an useful tool for mitigating volcanic secondary hazards, such as wildfires.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Assessing lava flow hazards in distributed volcanic fields using a lava library: Example from the Eastern Snake River Plain volcanic field (Idaho, USA)

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We propose a strategy to efficiently evaluate lava flow hazards to people and infrastructure arising from the eruption of lava flows from new vents in volcanic fields. This type of hazard assessment requires (1) a fast and reliable model to simulate lava flows, (2) a method of identifying regions of a volcanic field from which lavas may erupt that can impact an area of interest, and (3) a library of simulation results that can be used to assess hazards from a broad range of source vents and a broad range of statistical models, particularly as these data and statistical models change with time. The utility of a lava library of simulation output is demonstrated using MOLASSES. The library is constructed to help forecast lava flow hazards on the eastern Snake River Plain, a vast and active distributed volcanic field. More than 300,000 simulations are conducted using cloud computing resources. The advantages of creating a lava library are: (1) it can be used with a variety of statistical models of the spatial density and eruption source parameters of lava flows, without re-running simulations when these models change; (2) the library can be used to consider a variety of deterministic scenarios; and (3) the lava library documents the model input and output used to construct the hazard assessment;. We suggest the lava library concept is generally applicable to distributed volcanic fields, can be used to help guide further investigations and can be used to raise awareness of lava flow hazards.

Theme: 6. Hazard, Risk and Impact

Session 6.3: Volcanic hazards: mapping, susceptibility and probability

Allocated presentation: Poster

Outdoor CO2 hazard at Puerto Naos and La Bombilla (La Palma, Canary Islands): a numerical modelling approach.

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The 2021 Tajogaite eruption in Cumbre Vieja volcano (La Palma, Canary Islands) started on Sep. 19, 2021, and lasted 85 days, caused extensive damages. Since the middle of November 2021, some areas, located about 5 km SW of the eruptive centre have been affected by intense diffuse CO_2 emission. Among them are the urban centres of La Bombilla and Puerto Naos. These emissions prevented the population of these two centres from returning to their houses because of high concentrations of CO_2 in indoor and outdoor environments. In this work, we model the CO_2 dispersion process in Puerto Naos to obtain hazard maps with the maximum CO_2 concentrations in the outdoor. To achieve these results, we combined field measurements with numerical modelling, achieved using the software TWODEE-2, a code for modelling the dispersion of heavy gases based on the solution of shallow water equations. For this purpose, we used a detailed digital topographic model, including the edifices of Puerto Naos. We determined the gas emission rates from discrete source points in no-wind conditions using a trial-and-error approach. Subsequently, we repeated the numerical modelling, keeping the same sources and simulating all the realistic wind conditions in terms of direction and intensity. For each simulation, we determined the maximum CO_2 concentration at different elevations from the ground. This allowed obtaining a hazard map with the maximum CO_2 outdoor concentrations for each part of the town.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Talk [Invited]

Ash Concentration Forecast at VAAC Buenos Aires

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In the coming years, Volcanic Ash Advisory Centers (VAAC) will have to provide a new product called Quantitative Volcanic Ash Information (QVA) to optimize the use of airspace in the presence of ash in the atmosphere. The QVA consists of numerical ash concentration forecasts that provide deterministic and probabilistic information taking into account established thresholds of danger for aircraft, which correspond to low, medium, high, and very high concentrations. In this context, the Buenos Aires VAAC is developing an ensemble-based ash concentration forecast system using the FALL3D dispersal model. Preliminary model sensitivity studies determined that the input parameters whose uncertainty generates the greatest impact on model outputs are the height of the eruptive column, the shape of the emission profile, and the meteorological field. Based on this, ensemble-based simulations are generated by slightly changing these critical parameters, which allows quantifying the uncertainty in the transport and dispersion of the ash and giving the range of possible affected areas according to the different concentration thresholds. The simulations are verified with the detection and quantification of ash mass load retrieved from satellite observations. Trying to improve the ensemble by weighting the simulation that presents the best performance to the satellite data. This work continues to be developed in parallel with the standardization best practices shared among the 9 VAACs within the framework of International Civil Aviation Organisation (ICAO) and the collaboration across VAAC's modelers groups within the World Meteorological Organization's Advisory Group on Volcanic Ash Science.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Talk [Invited]

Operational ashfall forecasting in New Zealand: Current status and future perspectives

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All of Aotearoa-New Zealand's (NZ's) active volcanoes can erupt explosively, potentially dispersing ash across much of the country. Ash can be highly disruptive and damaging to the agricultural industry; critical infrastructure, including transport, power and water supplies; and human health. During eruptions, rapid and reliable ashfall forecasts are necessary to inform impact assessments and enable infrastructure and emergency managers to make informed decisions. GNS Science, through the GeoNet programme, has responsibility for monitoring NZ's volcanoes, as well as providing associated advice products, including ashfall forecasts. Through collaboration with the NZ MetService, ashfall simulations are performed every 6-hours for various eruption scenarios at 10 different eruptive locations, using the most up-to-date high-resolution meteorological forecast. From the model outputs, ashfall forecast maps are automatically generated and made available to duty personnel through a dashboard. In the event of an eruption, duty personnel can select the most appropriate scenario and insert the relevant map into an ashfall forecast template document, which can then be disseminated to emergency and infrastructure managers, as well as the public and media. Limitations of the current system include inefficiency in updating forecasts with observed data, an inability to produce probabilistic forecasts in response, and a lack of uncertainty information in the disseminated forecast. Current and future work to try and address this includes the development of new tools to rapidly characterise eruption source parameters in near-real-time, as well as continued engagement with next- and end-users to ensure that disseminated forecasts meet user-needs in regard to accessibility and usability.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Talk

Modelling the transport and dispersion of a co-PDC ash cloud: an evaluation of source geometry and mass eruption rate

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Pyroclastic density currents (PDCs) are gravity currents that frequently form during explosive volcanic eruptions. These ground-hugging density currents consist of high-temperature mixtures of pyroclasts (e.g., ash), lithics, and gas. These flows have the potential to generate co-PDC plumes, which detach from the underlying PDC as they buoyantly rise into the atmosphere. Co-PDC plumes, comprised of fine-grained ash particles and hot gas, can reach heights of tens of kilometres, potentially dispersing large volumes of ash over continental scale areas, impacting the environment, and posing a risk to aviation. Owing to their formation mechanism co-PDCs have unique characteristics, such as a restricted, fine (e.g., < 90 μm) particle size distribution and a high-aspect ratio, irregular shaped source geometry. Despite the frequency of their occurrence, the atmospheric dispersion model, NAME, used by the London Volcanic Ash Advisory Centre, has never been applied to co-PDC plumes. This study performed a sensitivity analysis to determine which co-PDC source parameters are important for modelling these plumes. Variations in the source geometry, i.e. total area and aspect ratio, show only a minor impact on the modelled plume location and concentration. Whereas plume heights, and hence associated mass eruption rates, show a significant impact on the area, location, and concentration of the modelled plume.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Talk

Estimating the intensity of explosive volcanic eruptions using volcanic cloud spreading rates

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The dynamical evolution of volcanic plumes has important implications for the prediction of ash cloud formation and dispersal, and its associated hazards. Volcanic ash transport and dispersion models rely on input eruption source parameters, including the eruption intensity, often termed mass eruption rate (MER). Two of the most popular methods to estimate MER are: (i) inverting from plume height using a volcanic plume model, most commonly a simple empirical relationship between MER and height; and (ii) reconstruction after the eruption from the duration and the deposit-derived total mass of tephra. Estimates of MER from these methods commonly differ by 1-2 order of magnitude, limiting our understanding of volcanic plume dynamics. Here, we expand on a third method, estimating MER from the satellite-measured growth rate of volcanic clouds, which has only been applied to a select few eruptions to date. Previous iterations of this method are also not applicable for the full range of eruption intensity and wind conditions governing volcanic cloud spreading. We will present a comparison and suggest improvements to existing methodologies and apply these methodologies to a range of plume types. By systematically comparing the spreading-derived MER estimates to those derived from plume height measurements, we provide further constraints on MER and its uncertainty. This will lead to better forecasting of ash dispersal during explosive volcanic eruptions, as well as development and improvement of existing plume models.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Talk

Quantitative Volcanic Ash (QVA) – A new operating requirement for Volcanic Ash Advisory Centres (VAACs)

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A global network of Volcanic Ash Advisory Centres (VAACs) provides advice and guidance to the aviation industry on the presence of volcanic ash in the atmosphere, to support decision-making on flight safety. Traditionally, forecasts have indicated the expected location of the ash cloud, in the form of a simple polygon, up to 18 hours ahead, referred to as a Volcanic Ash Graphic (VAG). A new service has now been defined by the International Civil Aviation Organisation (ICAO) which stipulates that all VAACs move towards providing quantitative forecasts in the form of 4D gridded datasets of ash concentrations, probabilities of exceeding prescribed thresholds, and new sophisticated polygons in IWXXM format. This new capability is being referred to as Quantitative Volcanic Ash (QVA). We will present the scientific and technical development of the operational modelling system used by the London VAAC to deliver QVA compliant forecasts. We will focus on the requirement to generate probabilistic forecasts for the first time, outlining their development, known limitations and further research and development requirements.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Talk

KAIROS AI-digital solution: a novel approach to forecasting the transport of SO2-rich volcanic plumes

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Aviation and the atmosphere are deeply interconnected, making a solid understanding of meteorological processes vital to passenger safety. However, several atmospheric factors remain significant challenges for aviation operations, including severe weather, space weather, and natural airborne hazards. This study specifically examines the effects of volcanic eruptions on aviation, focusing on the dispersion of volcanic SO_2 in the atmosphere. After highlighting the potential damage to aircraft caused by flying through volcanic plumes (from SO_2-rich eruptions, continuous degassing, or anthropogenic sources), this work aims to enhance the quality of SO_2 cloud data provided to the aviation community using artificial intelligence (AI). Our system develops its algorithms by incorporating both historical data (spanning several months) and near-real-time data inputs (delivered within 10 minutes to 3 hours). Leveraging advanced SO_2 observations from geostationary (GEO) and low Earth orbit (LEO) satellite sensors operating in the ultraviolet and infrared spectral ranges, the KAIROS system seeks to offer aviation stakeholders precise digital SO_2 forecasts with longer lead times. These forecasts will be compatible with decision-support tools, enabling stakeholders to mitigate the impacts of volcanic clouds on their operations. By providing accurate AI-based SO_2 forecasts earlier in the air traffic flow management process, aviation stakeholders will be better equipped to minimize operational disruptions. Forecasting SO_2 transport around volcanoes is crucial for reducing population health risk and benefiting civil protection and government agencies.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Probabilistic Modelling of Volcanic Ash: Eruption Source Parameter Uncertainty

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Volcanic ash clouds represent a significant hazard to aviation. To mitigate the risk, a global network of Volcanic Ash Advisory Centres (VAACs) is responsible for providing guidance on the presence of ash in the atmosphere. Forecasts are generated using atmospheric transport and dispersion models, underpinned by observations and driven by meteorological data. To initialise simulations the release of ash into the atmosphere must be defined, these are referred to as Eruption Source Parameters (ESPs). Notably, the height over which the ash resides and Mass Eruption Rate (MER), are leading order parameters, yet remain challenging to constrain during real-time event response. This study applies two new tools, MERPH (Woodhouse, 2024) and PVA (Williams et al., Submitted) to constrain uncertainty in ESPs and meteorological data for simulations of ash clouds using the Numerical Atmospheric-dispersion Modelling Environment (NAME). MERPH uses large historical datasets and Bayesian methods to explore the relationship between plume height and MER. PVA provides a computationally efficient statistical framework for propagating uncertainties on ESPs in atmospheric dispersion model simulations using ensemble meteorology, generating probabilistic forecasts. We analyze the eruptions of Raikoke (June 2019) and Shiveluch (April 2023), aiming to improve uncertainty representation in ash dispersion simulations, focusing on plume height and MER. Using MERPH and PVA, we seek to quantify these uncertainties to enhance probabilistic forecast reliability. We compare probabilistic and deterministic outputs, considering the influence of the uncertainty on ESPs and meteorological data. Our results highlight the importance of representing ESP uncertainty for operational forecasts for the aviation industry.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Evaluation Metrics for Volcanic Ash Cloud Forecasts

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Volcanic ash dispersion simulations can be evaluated with observations, particularly satellite imagery and retrievals, to inform how well the dispersion models simulate volcanic ash cloud location and concentration. In both volcanic ash dispersion and the wider community many evaluation metrics have been proposed and used, and effective evaluation would benefit from standardization of the metrics. Evaluation metrics can be useful for both model development and in-event decision making. They allow decisions to be made about whether to implement new developments into dispersion models, by comparing simulations to historic observations with different model setups. During an event, metrics can support decision making, for example at Volcanic Ash Advisory Centres (VAACs), to assess whether the forecast is optimal and determine if changes to the simulation e.g., source terms or meteorological data used, would deliver forecasts which better match recent ash observations. To explore using evaluation metrics in a systematic way we calculate a range of evaluation metrics for 5-day NAME ash dispersion simulations of the Raikoke 2019 eruption compared to satellite observations re-gridded with the same horizontal scale. We find that no one metric captures all that we are interested in for both model development and in-event decision making. Different metrics quantify different aspects of the ash cloud and are therefore useful in different ways. Evaluation of volcanic ash forecasts for both model development and in-event decision making may require a range of metrics to fully evaluate the model output.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Using Simulated Radiances to Understand the Limitations of Satellite-Retrieved Volcanic Ash Data and the Implications for Volcanic Ash Cloud Forecasting

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Volcanic Ash Advisory Centers (VAACs) have generated volcanic ash forecasts for the aviation industry since the mid-1990s. The excellent spatial and temporal coverage of satellite data makes them critical to the validation of ash dispersion model forecasts. This study investigates the limitations of satellite-retrieved volcanic ash data through the production of simulated radiances for a range of ash cloud properties encompassing the satellite retrieval's sensitivity. We run a detection and retrieval algorithm (Francis et al., 2012, https://doi.org/10.1029/2011JD016788) on these simulated ash clouds and assess the sensitivity and performance of the algorithms. Expected limitations are highlighted, including a lack of sensitivity to particles larger than ~10 μm in radius and challenges in accurately retrieving heights in the stratosphere. However, other previously poorly defined limitations are also constrained, such as the reduction in sensitivity as ash column loading increases in optically thick ash clouds and increasingly underestimated column loading when column loadings are >~7 g m^{-2}. We consider the implications of the identified limitations when using satellite-retrieved ash column loadings to verify dispersion model output. We show that, accounting for the limitations of the satellite retrieval, a significant proportion of mass in the model output can lie outside the sensitivity range of the satellite detection and retrieval. This demonstrates the importance of understanding observations' limitations when comparing to model output. This presentation will briefly describe the study and then discuss how the results could be utilised in operational volcanic ash forecasting processes, including model evaluation and data insertion, inversion or assimilation.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Exploring the Relationship between Plume Height and SO2 Flux for Explosive Eruptions

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Explosive volcanic eruptions can release large quantities of gas, including sulphur dioxide (SO_2) into the atmosphere. Elevated concentrations of SO_2 can pose a health hazard or impact aircraft components and hence maintenance cycles. Exposure levels are determined by the extent of the SO_2 cloud and concentrations. Forecasts of the expected behaviour of volcanic SO_2 clouds can be generated using atmospheric transport and dispersion models, driven by meteorological data and initialised with information about the source of the pollutant into the atmosphere. Key source parameters are the height over which the gas is being released and the SO_2 flux. Here we consider the feasibility of using an empirical relationship to describe SO_2 flux as a function of plume height, as an operational tool for real-time response when measurements are scarce. We make use of two databases. The Multi-Satellite Volcanic Sulphur Dioxide Database which compiles global emissions derived from ultraviolet satellite measurements, and the Independent Volcanic Eruption Source Parameter Archive (IVESPA) database. We use recorded information on the duration, total erupted ash mass, ash plume top height and spreading height, and the height of the SO_2 plume, for events common to both databases. We explore several approaches for fitting a relationship between the observations of plume height and SO_2 flux and discuss the appropriateness of each. We conduct case studies from which we outline the advantages and limitations of using an empirical approach for defining SO_2 flux from explosive eruptions for operational response.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Forecasting tephra deposition: the impact of input parameter uncertainty on tephra deposition accuracy

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Accurate forecasts are critical to help mitigate the risks of volcanic hazards to society. While post-event modelling, or hindcasting, allows for input parameters to be reasonably well constrained through observations (e.g., plume height), or post eruption analyses (e.g., TGSD), forecasting these input parameter ranges prior to an eruption is much more uncertain. In these cases, forecasts rely on probabilistic estimates from limited data (e.g., IVESPA database) and expert judgement. From an impact-based perspective, a forecasted ashfall of 3mm rather than 2mm may have little impact, but forecasting 50mm when 200mm occurs could have major consequences and cause significant risk to life. Tephra deposition, even during hindcasts where input parameters are constrained through observation and post-eruptive studies, can deviate by up to a factor of 5 from actual ground deposits using current tephra dispersal models (e.g., Fall3D, Tephra2, HAZMAP). Correctly quantifying this uncertainty is also crucial to hazard mitigation. This research explores how input parameter ranges in tephra dispersion models Tephra2 and Fall3D influence ash deposition forecasts in the context of the next eruption. Specifically, we want to know how well input parameter ranges based on uninformed priors (i.e., we know nothing about the next eruption) and informed priors (i.e., we know things such as volcano type and previous eruption sizes and styles) can produce robust tephra deposition forecasts compared to real deposit data. Using the example of the 17 June 1996 Mount Ruapehu eruption in Aotearoa New Zealand, we evaluate how these priors impact forecast robustness and accuracy.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

MetPrep: A model-agnostic meteorological pre-processor for emergency applications in local volcanic emission dispersal

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Pollutant transport modelling is used to simulate pollution events (such as volcanic emissions) and guide mitigation strategies. When focusing on local impacts, atmospheric circulations influenced by the topography around the source become vital in capturing the correct dispersal pathways. However, given the urgent nature of such events, employing dynamical downscaling models (e.g. the Weather Research and Forecasting model; WRF) in high-enough resolution is often impossible within the emergency time constraints. As a trade-off between accuracy and computational time, diagnostic wind models are often employed to adjust the wind fields of global datasets by applying first-order topographic corrections. Numerous such models exist, but are either based on legacy code, or tied to particular transport models. To counteract this, as part of the EU Center of Excellence for Exascale in Solid Earth project (ChEESE-2P), we have developed a model-agnostic meteorological preprocessor (MetPrep). MetPrep ingests coarse meteorological data, applies topographic corrections based on the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second digital elevation map and creates output mimicking the format of WRF, allowing for the use of any model that uses WRF data as input (e.g. FALL3D, FLEXPART, HYSPLIT). As a pilot study we couple MetPrep with FALL3D and focus on the Tajogaite eruption at Cumbre Vieja, La Palma (September-December 2021), which highlighted difficulties in accurately forecasting gas dispersal over complex topography leading to severe impacts on human activities. This study is part of the grant PCI2022-134973-2 funded by MICIU/AEI/10.13039/501100011033 and by the European Union “NextGenerationEU”/PRTR and Germany’s Excellence Strategy grant (EXC 2077).

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Tailored transport and deposition forecasting of volcanic emissions for field campaigns: Results from the VOLCOM campaign at Sakurajima volcano, Japan

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Field campaigns are critical for understanding the Earth system. Given their cost and complexity, precise knowledge of target phenomena is crucial. Dynamical downscaling during campaigns can offer high-resolution forecasts to aid decision-making and improve success rates. This study introduces a probabilistic forecast algorithm tailored for volcanic emission field campaigns, demonstrated using data from the Volcanic Emissions Observation and Modeling (VOLCOM) campaign at Sakurajima, Japan, in November 2023. Sakurajima was selected for its prolonged activity and proximity to a densely populated area (>1 million residents within 20 km). Recent increases in SO_2 emissions and reduced explosive activity provided ideal conditions for ground-based mobile Differential Optical Absorption Spectroscopy (DOAS) observations, used to validate forecasts from the Weather Research and Forecasting (WRF) and FALL3D models. During the campaign, SO_2 emissions were monitored, revealing strong signals (Slant Column Density $>10^{18}$ molecules cm^{-2}). Comparisons of DOAS observations with forecasts showed good agreement, with Pearson coefficients of 0.54–0.64 when knowledge of the emission height was excluded and up to 0.92 when it was considered. These results underscore the value of high horizontal resolution for accurately simulating local circulations and highlight the importance of scenario-based forecasting to capture anticipated conditions. This approach significantly contributed to the VOLCOM campaign's success, demonstrating the potential of tailored forecasts to enhance field campaign outcomes.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Quantitative Volcanic Ash Forecasting for Aviation – A new opportunity for volcanic ash research and collaboration

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The Volcanic Ash Advisory Centres (VAACs) provide guidance to the aviation industry on the presence of volcanic ash in the atmosphere, to support decision-making on flight safety. In 2025 the VAACs will start to deliver a new service under the International Civil Aviation Organisation (ICAO) which, in addition to the presence of ash, stipulates the provision of 4D quantitative forecasts of ash concentrations and probabilities of exceeding certain prescribed thresholds. This is being referred to as Quantitative Volcanic Ash (QVA). The successful quantitative volcanic ash forecast relies on: data, observations and modelling of eruptive source parameters; suitable numerical weather prediction; a dispersion model with relevant processes; observations of ash in the atmosphere; a data fusion capability to enable the observations to be used in the modeling; suitable products, communications and verification methodologies. To construct a 'full' probabilistic forecast requires, in addition, that probabilities are understood represented in all these areas. Like all real-world services no one expects every or even most aspects to be captured or represented with the advent of QVA. However, the evolution of quantitative analysis from a largely research function to a global near real time forecast service opens up numerous opportunities to make greater use of existing data/capabilities and in how we develop new ones. This talk will step through the components required for a quantitative volcanic ash forecast, highlighting the different opportunities that this creates for using and improving our community's science and data.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Optimizing lava flow simulations using a Markov Chain Monte Carlo approach

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Effusive eruptions in basaltic volcanoes pose significant risks especially to the human infrastructure. Accurately predicting lava flow dynamics and their likely paths remains a challenge, due to the numerous factors that influence their motion and emplacement. This study introduces a novel application of the Metropolis-Hastings algorithm, a Bayesian approach based on Markov Chain Monte Carlo (MCMC) method, for the real-time modeling of lava flows. The approach optimizes the prediction of lava flow behaviour by exploring the parameter space and deriving posterior distributions, based on multi-source satellite data and observed characteristics of the eruption. The method relies on the GPUFLOW model, a cellular automata-based tool, developed at INGV-Catania to simulate lava flow dynamics. Key input parameters include lava physical properties, topography, vent location(s), and TADR (time-averaged discharge rate) data. The Metropolis-Hastings algorithm refines the simulation over time, adjusting for uncertainties, such as the position of active vents, the distribution of TADR values, and the lava's water content, which influences its viscosity. The optimization process integrates satellite data, minimizing discrepancies between the simulated and observed flow field. This methodology has been applied to the effusive eruption that occurred at Mt. Etna (Italy) between 27 November 2022 and 6 February 2023, which produced a complex lava field with an extensive lava tube system. The results highlight the potential of the use of Bayesian approach to make more accurate predictions of lava flow paths and their extents, helping us to refine eruption monitoring, hazard assessment, and planning of volcanic risk management strategies.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Eruption source parameter needs of the operational ash dispersal modelling community

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Eruption Source Parameters (ESPs) are crucial for characterising volcanic eruptions and are essential inputs to numerical models used for hazard assessment. Key ESPs for simulating ash dispersal associated with explosive volcanic eruptions include eruption plume height, mass eruption rate, eruption duration and grain-size distribution. ESPs may be estimated from ground or satellite observations, or, where observations are not available, from studies of previous eruptions or eruptions from analogous volcanoes, with additional insight provided by analysis of unrest signals. Ash dispersal modelling in an operational context, e.g. ash cloud forecasting by Volcanic Ash Advisory Centres (VAACs), requires ESPs that can approximate eruption conditions well enough for outputs to be useful for decision making. Currently, ash dispersion forecasts are communicated as 2D plots of forecast ash dispersion. However, improved computational efficiencies and recent changes to VAAC operational procedures mean that these plots will be replaced by 4D probabilistic products. The modelling approaches to produce these new products require more complex input parameter information than is currently available. To better understand these input requirements, we conducted a survey of the VAACs to detail the type and format of ESPs used in the numerical modelling approaches. While there are some differences in the specific approaches and needs of the different VAACs, survey results highlight an increasing need for uncertainty information on ESPs. This presentation will highlight key results from the survey with the aim to inform the volcanic community so that improved ESPs can be developed for operational forecasting.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Techniques for Validation and Improvement of Volcanic Ash Concentration Ensemble Forecasts

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The dispersion of volcanic ash poses a significant threat to aviation safety. To mitigate this risk, Volcanic Ash Advisory Centers (VAACs) issue volcanic ash advisories which include information about the observation and the dispersion forecast of volcanic ash clouds. The Buenos Aires VAAC, which currently uses the FALL3D model in a deterministic way, is transitioning towards an ensemble-based forecasting strategy in alignment with the implementation of Quantitative Volcanic Ash (QVA) Information between the end of 2024 and 2025. This study outlines a strategy for calibrating and validating model ensemble, using the eruption of the Ubinas volcano as a case study. The methodology combines satellite products for volcanic ash detection and mass loading estimation from VOLCAT in combination with the ensemble members, enabling an assessment of the uncertainty associated with model input parameters. By analyzing this uncertainty, the study aims to enhance the accuracy of volcanic ash concentration forecasts, optimizing decision-making processes for aviation safety. The findings of this work will contribute to the generation and optimization of critical information, improving volcanic ash concentration forecasts in the years to come. Keywords: Volcanic Ash, VAAC, Quantitative Volcanic Ash Information, Numerical Modeling, Ensembles.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

The North Atlantic Volcanic Hazards Partnership: An Introduction

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The North Atlantic Volcanic Hazard Partnership (NAVHP) was established during the 2010 eruption of Eyjafjallajökull, to provide a coordinated approach to operational response to volcanic unrest and eruptions in the North Atlantic, specifically in Iceland and Jan Mayen. The partnership is underpinned by a Memorandum of Understanding between the Icelandic Meteorological Office, the Met Office UK, the UK National Centre for Atmospheric Science and the British Geological Survey. The primary objectives of the partnership are to: a) enhance capabilities for the monitoring, measurement and modelling of pre-eruptive and eruptive activity in Iceland and Jan Mayen and resultant characteristics of eruptive plumes and volcanic clouds and b) to facilitate provision of coordinated volcanic hazard related science advice and services to domestic and international stakeholders in civil protection, aviation, media and other sectors. Since 2010, the partnership has met twice yearly. During these meetings, the Iceland Meteorological Office provides an update on Icelandic volcanic activity, with each partner then providing progress reports on their respective capabilities for volcanic and eruptive plume monitoring, modelling and underpinning science. The partnership also undertakes joint activities to advance capabilities, for example, exercises designed to simulate information exchange and modelling in real-time during eruptive activity. During our 2024 Autumn meeting, we reflected on progress in tool development for monitoring and responding to volcanic eruptions undertaken in Iceland and the changing communication requirements between volcano observatories and volcanic ash advisory centers related to the production of new quantitative hazard products. This presentation will summarise these developments and changes.

Theme: 6. Hazard, Risk and Impact

Session 6.4: Operational hazard forecasts: source parameters and model evaluation

Allocated presentation: Poster

Operational lava flow forecasting: An approximate Bayesian computation particle filter for nonlinear transient systems

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During effusive volcanic crises, generating timely and well-calibrated lava flow forecasts is a critical need for volcano observatory and emergency management operations. As has been shown by recent examples at Mauna Loa, Piton de la Fournaise, and in Iceland, advances in lava flow models and computational architectures have enabled real-time generation of lava flow forecasts in operational observatory environments. Part of this success is owed to the generally slow evolution of lava flows, which provides the time needed to adjust model parameterization based on observations. However, the highly nonlinear physics of lava flows, together with the heterogeneous nature of lava flow observations (e.g., indirect estimation techniques and a mix of both qualitative and quantitative observations) presents significant challenges in application of data assimilation techniques, largely due to the complexity of characterizing model-observation errors. These challenges lead naturally to the application of approximate Bayesian computation (ABC), which enables the assimilation of heterogeneous data sources without requiring precisely characterized errors. ABC is an ensemble-based technique that is well-suited to general particle filter approaches without assumptions about model linearity or error distributions. This work focuses on the development of an ABC-based particle filter for updating estimates of model parameters in operational lava flow forecasts as well as its application to the 2022 Mauna Loa eruption. Applied recursively as new observations are available, this approach is shown to successfully update lava flow model parameters while providing an estimate of the uncertainty in the posterior forecast.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Talk [Invited]

Model-based lava flow hazard assessment: pre- and syn-eruptive forecasts with uncertainty quantification

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During effusive eruptions, lava flows can displace populations and destroy homes, roads, and other infrastructure. Although the impacts of individual flows tend to be highly localized, lava flows can threaten wide areas over multiple eruptions since they cool and create new topography, inhibiting future flows from reoccupying old flow paths. Accordingly, lava flow hazard assessments can span a wide range of temporal and spatial scales from regional assessments of inundation on geologic time scales to forecasts of individual flows relevant over the coming few days. Increasingly, computational models are being used to inform short- and long-term inundation assessments either to augment or replace traditional assessments based on geological mapping or historical precedent. However, there are major challenges, including constraining the range of model validity, parameterizing models, and characterizing and quantifying uncertainty. Uncertainty quantification is a particularly large concern for short-term modeling since there is not typically time to run many models or construct a precise statistical model during a crisis. By contrast, long-term assessments typically embed some aspects of uncertainty (e.g., vent location), although comprehensive uncertainty quantification is often impractical at this scale. Here, we detail recent and ongoing model-based lava flow hazard assessment efforts targeting multiple timescales and user needs including forecasts during the 2022 Mauna Loa eruption and planning for future eruptions of Kīlauea and Mauna Loa. In particular, we focus on tracking sources of error in these assessments enabling estimation of model product uncertainty and meeting user needs for “most likely” and “worst case” products.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Talk

The effects of lull and peaks in effusion rate on lava flows propagated on slopes: insights from analog experiments

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Lava flows represent a hazard to populations and infrastructure proximal to volcanoes. Topography is one of the primary external variables that impacts flow emplacement, affecting likely paths. The confluence of variable effusion rates and topography may produce unique flow behaviors that may improve understanding of lava flow emplacement. We conducted analog experiments utilizing polyethylene glycol wax to investigate how changes in extrusion rate at the source impact flow propagation on low, medium, and high slopes. We focused on the following flow emplacement modes: surface and marginal breakouts, inflation, and tube formation. We performed 72 experiments using 2 different effusion rate patterns to address the following controls on lava flow emplacement: a lull – a stepwise decrease in extrusion rate (n = 36) and a peak – a stepwise increase in extrusion rate (n = 36). For each condition (lull vs peak), we varied the slope between low (~7°), medium (~16°), and high (~29°). We controlled for wax and ambient water temperature, extrusion rate, and slope. Emplacement modes varied by condition, extrusion rate, and slope, with resurfacing independent of all, inflation occurring at low slopes or under low extrusion rates, and tube formation preferred under peak conditions regardless of slope. Steeper slopes resulted in narrower channelized flows, while flows emplaced on shallower slopes were wider, thicker (in cases of inflation and resurfacing), and displayed more complex morphologies. Post-emplacement morphologies were modified by drain out especially at steeper slopes, which may not preserve the finer surface textures produced during an eruption.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Talk

Lava flow susceptibility map for Nyiragongo and Nyamulagira volcanoes, Virunga Volcanic Province: A support for risk management?

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The Virunga Volcanic Province (D.R.Congo) hosts two active volcanoes, Nyiragongo and Nyamulagira, producing each hazardous lava flow eruptions but with contrasted lava rheology, flow geometries, and recurrence intervals. The region between Goma and Sake, on the shores of Lake Kivu, is exposed to lava flows from both volcanoes. Here we present the method used to produce a combined lava flow inundation susceptibility map that integrates both volcanoes, using the topography-controlled Q-LAvHa probabilistic model. The probability of vent opening for the next eruption is spatially constrained for each volcano based on mapping of eruptive vents and fissures. The Q-LavHa model is then calibrated separately for each volcano, considering several historical lava flows. The accuracy of this susceptibility map has been validated by the May 2021 lava flow of Nyiragongo and the 2024 Nyamulagira eruption. Although the scientific development of this map is based on a volcano-specific calibration, its main value lies in its potential application for disaster risk management. This map can primarily be used to assess the exposure of key infrastructure to lava flow hazards in the Goma-Sake urban area. It could also support urban planning, emergency preparedness, and response strategies, ensuring contextualized risk reduction measures. However, integrating such scientific assessment into official urban planning and risk management frameworks represents a major challenge. Although co-designed with the relevant authorities, this process has not yet enabled the map to be effectively embedded into these frameworks, nor used to enhance resilience and reduce vulnerability in volcanic risk areas.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Talk

Rapid response to effusive eruptions using satellite infrared data: The March 2024 eruption of Fernandina (Galápagos)

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On March 3, 2024, a new effusive eruption began from a semi-circular fissure on the southeast flank of Fernandina volcano (Galápagos archipelago, Ecuador). Although the eruption posed no specific risks to people (the island is uninhabited), it provided the opportunity to test a rapid response system to effusive eruptions, based on satellite infrared (IR) data. In this work, we illustrate how the analysis of data coming from multiple IR sensors allowed to monitor the eruption in near real time (e.g. 1-4 hours from image acquisition) by providing recurrent updates on the following parameters: *(i)* lava discharge rate and trend, *(ii)* erupted lava volume, (iii) lava flow area, *(iv)* active flow front position (*v*) flow velocity and *(vi)* location of active vents and breakouts. The workout demonstrates the efficiency of satellite thermal data in responding to effusive eruptions and maintaining situational awareness at volcanoes where little ground-based data are available.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Talk

Lava flow monitoring and modelling during the 2021-2024 Reykjanes peninsula unrest, SW Iceland

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The fires on Reykjanes Peninsula are characterized by fissure eruptions that take place ~30 km SW of the Reykjavík capital area, close to urbanized areas and essential infrastructure. The first three eruptions (2021–2023) in the Fagradalsfjall volcanic system were low-intensity eruptions where the primary challenge was ensuring safety of visitors. In contrast, the seven recent eruptions within the Svartsengi volcanic system (Dec 2023–Dec 2024) had very high initial effusion rate and caused damage in the evacuated town of Gríndavík (~3,800 people), damaged roads, pipelines and power lines, and temporarily disrupted the water supply to ~30,000 people. The volcanic unrest is ongoing and continues to threaten Grindavík, the Svartsengi geothermal powerplant, and the tourist attraction the Blue Lagoon, and hence barriers have been built around these locations as defense. The difference in eruption intensity, fissure length, eruption frequency and vicinity to inhabited areas and critical infrastructure have provided major challenges calling for further developments for the lava flow monitoring and modelling. Here we present and discuss these developments which include: 1) Frequent topographic measurements of changes to the lava flow fields and barriers; 2) Pre-eruption lava flow simulations for hypothetical eruptive fissures; 3) Real-time observations of fissure locations and lava flow fronts when eruptions start; 4) Rapid initial effusion rate estimates and initiation of lava flow simulations; 5) Daily mapping of the lava flow field, vent configuration and evaluation of

status at barriers and 6) Data sharing and rapid communication among the general public, private companies and government institutions.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Talk

The layout and elevation design of the lava barriers on the Reykjanes Peninsula, Iceland

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In March 2021, the Department of Civil Protection and Emergency Management in Iceland, appointed a group of specialists (engineers and volcanologists) to look into ways to protect important infrastructure on the Reykjanes Peninsula, which had been dormant for about 800 years. The work started immediately. During the Fagradalsfjall eruption in 2021, barriers were tested. The real test came in late 2023 when land started to rise underneath Svartsengi Geothermal Power Plant (SGPP) and the town of Grindavík. Work on the lava barriers for the SGPP started early November 2023 and early January for Grindavík. On 19th of December 2023 the Sundhnúkur fissure erupted, with six additional eruptions in 2024. The barriers are now 13 km in length with height up to 25 m. They have so far protected the infrastructure as intended, even though a fissure in January 2024 opened through the barrier and another one at the very edge of Grindavík. The talk will focus on the design of the barriers which include. 1) The main tool: lava flow modelling using the Bingham fluid option in HEC-RAS; 2) Calibration of parameters; 3) The design lavas and their evolution/re-evaluation between events; 4) How well did the simulations fit with reality; 5) How the simulations have been used for the layout and elevation design of the barriers; 6) How a re-evaluation of the barriers is needed after each eruption; 7) How the simulations have been used to estimate minimum time before lava might reach important locations.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Enhancing Lagrangian numerical simulations of Lava Flows Using AI-based CFD emulators

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Lava flows exhibit complex fluid behavior characterized by non-Newtonian rheology, enabling them to overcome barriers, form tunnels, and inflict damage on affected areas. Mathematical modeling and numerical simulations are essential tools for quantitatively describing these flows and predicting potential scenarios without the risks associated with in-field studies. However, achieving an optimal balance between model accuracy and computational efficiency can be challenging. For instance, while Computational Fluid Dynamics (CFD) models provide reliable simulations of lava flows, they often come with high computational costs. Recent research has sought to address this by integrating CFD with Artificial Intelligence (AI) to enhance simulation performance. Here, we introduce a CFD emulator incorporating AI specifically designed for lava flows, capable of replicating their characteristic visco-thermal coupled behavior. This model adeptly manages various physical phenomena, including phase transitions, particle solidification, and the influence of air. We have conducted simulations under diverse physical conditions to validate the model's reliability and generalization capabilities. Furthermore, we investigated the impact of different parameters on lava flow modeling and the quantification of associated volcanic hazards. For example, we analyzed the influence of the effusion rate on eruption styles using satellite-derived estimates, facilitating a deeper understanding of varying eruptive behaviors without the risks of in-field assessments. Our results demonstrate the significant potential of integrating real-world measurements, numerical models, and AI to simulate lava flows, producing near real-time scenarios that are valuable for impact and risk assessment in complex eruption events.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Particle-based model for lava flows with fluid-solid phase transition

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Lava flows exhibit a strong dependence on temperature, which influences both the viscosity and the occurrence of phase transitions. The latter are a key factor in the evolution of the flow, determining the final emplacement, and the formation of geological features like lava channels and tubes. Lagrangian models offer significant potential for detailed simulations of lava flows because they efficiently handle highly irregular, dynamic free surfaces and complex phase interfaces, such as those between solid and liquid states. In this work, we present a threedimensional numerical model that combines Smoothed Particle Hydrodynamics (SPH) with the Lattice Spring Method (LSM) to simulate two-way phase transitions between solid and fluid phases. The model includes thermal conduction to account for heat exchange within the flow and with the ground, as well as surface heat exchanges to capture cooling effects due to radiation and air convection. The model is able to take into accont a temperature trange for the phase transiton, defined by solidus and liquidus temperatures, typical of mixtures, as lava is. This approach allows for the formation of a "mushy" region, where solid and liquid phases coexist. Our model captures the mechanical aspects of this transition which enables the simulation of a deformable crust whose strength varies with temperature. We apply this model to illustrative volcanic scenarios, demonstrating its ability to effectively capture the phase transitions within lava flows. These results underscore the importance of accurate phase transition modeling in understanding the complex behavior of lava flows in real-world volcanic contexts.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Analysis of lava flow emplacement and morphology using Synthetic Aperture Radar

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Monitoring and understanding lava flow emplacement and dynamics are critical for mitigating volcanic hazards but traditional ground-based observations are often limited by hazardous conditions or inaccessibility during eruption. Satellite-based Synthetic Aperture Radar (SAR) provides a powerful alternative, with its ability to penetrate clouds and operate day and night, observing ground surface changes. SAR backscatter, is strongly influenced by surface roughness, allowing for examination of flow morphologies, and textures across the flow through time. However, SAR backscatter remains underexploited for monitoring lava flow emplacement and morphology over time. Here, we demonstrate the potential of SAR backscatter for tracking lava flow progression and morphology. By applying pre-processing filters and temporal analysis techniques, we analyse spatial and temporal variations in SAR backscatter. We observed (1) variability in backscatter along lava flows, likely linked to differences in surface roughness, and (2) the ability to map flow progression with high temporal resolutions. For example, at Erta ’Ale Volcano, Ethiopia, we achieved 79% accuracy in flow extent extraction compared to manual inspection, with rougher, ‘Aʻā-like surfaces emplaced furthest from vent likely caused by cooling. The observed lava flow extents at Erta ’Ale could not be reproduced using lava flow simulations (Q-LavHa), with reasonable input parameters. This highlights the need for improved model calibrations and the importance of detailed observations to inform flow modelling and hazard assessment. Our findings demonstrate SAR backscatter as a valuable dataset for volcanic monitoring, complementing other remote sensing and ground-based methods, with potential for refining hazard assessment and lava flow modelling.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Developing the "Long-Term Lava Flow Hazard Zone Map for the State of Hawaii"

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The Hawaiian Islands are basaltic shield volcanoes formed by the Hawaiian hot spot. Five subaerial volcanoes—Kīlauea, Mauna Loa, Hualālai, Haleakalā, and Mauna Kea—are deemed active or potentially active, and lava flows are a primary hazard from an eruption at any of these volcanoes. The relative hazard posed by lava flows varies across the islands, dependent on factors including eruption style (related to a volcano's age and position relative to the Hawaiian hot spot), the location of potential vent areas, and local topography. At the time of writing (January 2025), the U.S. Geological Survey's Hawaiian Volcano Observatory is in the final stages of developing a lava flow hazard assessment for the entire State of Hawaii, which incorporates, updates, and revises past lava flow hazard assessments for parts of the state, including the 1992 *Map Showing Lava-Flow Hazard Zones, Island of Hawaii* by Wright and others. The state-wide assessment incorporates new geologic mapping, less well-known lava flow hazard maps from other islands, research, and an improved understanding of lava flow hazards. Additionally, zone definitions have been revised to be clearer and easier to understand, and special care has been given to ensure new hazard map is accessible for all users. In this contribution, we will share our process of updating, revising and expanding this important and iconic hazard map. If is published by the time of the IAVCEI Scientific Assembly, we will reveal the *Long-Term Lava Flow Hazard Zone Map for the State of Hawaii*.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Monitoring and Modeling Lava Flow Dynamics of the July 2024 Stromboli (Italy) eruptive activity: Insights from UAS Surveys and Petrological Analysis

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In the summer of 2024, Stromboli volcano exhibited a significant effusive activity, starting on the 4th of July with lava flows from eruptive fissures that opened in the upper Sciara del Fuoco slope. The activity culminated in a paroxysmal event on the 11th of July, producing a 5 km-high eruptive column and pyroclastic density currents flowing along the Sciara del Fuoco. In such a scenario, the emplacement mechanisms and inundation capability of erupted lavas are primarily modulated by topography, effusion rate, and rheology of lava, all parameters changing dynamically during the eruption. Accordingly, the effusive activity and the related morphological changes were closely monitored with repeated Unoccupied Aircraft System (UAS) surveys. The combination of UAS data (e.g., digital elevation model, effusion rate) with the petrological and rheological characterization of volcanic products (e.g., initial crystal cargo, crystallization sequence, viscosity) provided a unique opportunity to develop a multidisciplinary approach for the detailed characterization of both the erupted magma and the volcanic activity during an effusive eruptive event. The integration of this multidisciplinary data set allowed us to model lava flow emplacement and provide inundation scenarios, to benchmark their reliability and optimise the accuracy of numerical modelling results. The final objective is to establish a rigorous protocol for assessing the risk of lava flow invasion and its associated hazards through an interdisciplinary monitoring framework, applicable during future volcanic crises.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Data Assimilation for Probabilistic Forecasting of Lava Flows in Real-Time

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The monitoring of effusive volcanic eruptions involves processing multiple signals (volcanic tremors, ground deformation, satellite imagery...). However, the uncertainties inherent in these data, combined with the complexity of lava flow physics, make precise deterministic forecasts of lava flow propagation highly challenging. An ensemble-based probabilistic approach, combined with a robust numerical model of lava flow, addresses the uncertainties related to lava rheology and propagation. By integrating data assimilation techniques, this approach also accounts for uncertainties in observational data, producing data-informed forecasts. Using these methods, a real-time workflow has been developed to forecast lava flow propagation during eruptions by continuously incorporating new incoming data. Built around VLAVA, a new numerical model that simulates temperature-dependent viscous lava flow propagation over a complex topography, the workflow generates multiple combinations of model source parameters, creating an ensemble of lava flow simulations. The weight associated with each member of the ensemble can be adjusted in real-time based on their similarity to the observations. The aggregation of these weighted lava flow simulations results in updated probabilistic forecasts. In addition, lava fields extracted from satellite data can be directly assimilated into simulations, driving the model toward even more realistic lava flow predictions. This data-assimilation method has been coupled with satellite images processing and uncertainty evaluation modules which are key points for the workflow's accuracy and robustness. These developments have shown promising results when applied to historical eruptions of Mount Etna (Italy) and will be extended to other volcanoes, including Fagradalsfjall (Iceland).

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

User-guided application of model-based lava flow hazard assessment in Hawaii

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The Island of Hawai'i experiences frequent effusive eruptions that can impact surrounding communities, property, and infrastructure, while driving tourism for lava viewing. There is therefore a need for lava hazard information for a range of stakeholders. Previous hazard assessment efforts have ranged from the identification of areas at risk of lava inundation over decades to centuries, to short-term forecasts of where an active lava flow is heading. Computational modeling, integrated with improved digital terrain and monitoring data, is expanding opportunities to tackle these and other hazard products. Concurrently, engagement with emergency and land managers on the outstanding questions, spatial and temporal scales, content, design, and sharing of hazard information is guiding applications of these tools. Work on both simple flow routing and physics-based model-derived products has improved short-term forecasts for crisis response. However, user needs for planning have also inspired development of intermediate-term assessments, capturing where lava inundation may occur over present-day topography given uncertainty in eruption parameters like vent location(s) and effusion rates. These parameters could be based on eruptive history, such as relating sections of the rift zones that could become active to the inundation zones where flows would travel downslope. They could also be driven by a particular crisis, such as an intrusion, in which vent likelihood reflects geophysical evidence for dike propagation. These user-targeted results can be rapidly generated and help meet planning and response needs, although challenges remain in incorporating uncertainty. With feedback on test examples, we aim to develop and improve user-guided hazard products.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Hazards of perched lava lakes – high-volume subsurface spill and flow in the last phase of the 2021 Fagradalsfjall eruption, Iceland

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Perched lava lakes pose significant hazards due to their ability to suddenly release large volumes of molten lava during a breach or break through, often with effusion rates greatly exceeding those observed at the vent. During the final phase of the 2021 Fagradalsfjall eruption in Iceland, a perched lava lake formed, ponded and broke through. The resulting lava flowed through subsurface pathways into an upwelling zone and flooded the Geldingar valley with a large sheet flow with high effusion rate, endangering tourists and a hiking path downstream. Here, we evaluate the perched lava lake's size, volume loss during drainage, and effusion rates. These data are combined with post-eruption drone-based magnetic surveys to investigate the lava lake's evolution and subsurface lava transport pathways. Our results show that the perched lava lake acted as a temporary reservoir, with effusion rates 5-10 times the average vent effusion rate during the breakthrough. Although active for only three days during the six-month eruption, the upwelling zone discharged ~6 million m^3 of lava. Magnetic surveys delineate possible locations of the hidden subsurface lava pathways, which facilitated the rapid flow of lava into the upwelling zone. This study highlights the hazards of perched lava lakes and their ability to drain via subsurface pathways, emerging downstream as large sheet flows with a sudden, drastic increase in local effusion rates. By integrating remote sensing data with geophysical surveys, this work provides new insights into lava transport processes and emphasizes the value of multidisciplinary approaches in hazard assessment.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

2.5D Shallow Water Model For Lava Flows

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Volcanic eruptions, while unstoppable, often unfold at a pace that allows for real-time hazard assessment and response. Effusive lava flows typically advance at a few hundred meters per hour, giving scientists and civil protection the opportunity to simulate potential scenarios and prepare evacuation and safety plans during ongoing eruptions. We present a new shallow water model designed to simulate lava flows with high physical accuracy and computational efficiency, enabling its use in real-time forecasting of potential lava flow paths during ongoing eruptions. This depth-averaged model surpasses traditional shallow water models by incorporating several key enhancements: (i) a parabolic velocity profile to capture vertical variations; (ii) a non-constant vertical temperature profile to present thermal gradients; (iii) a viscoplastic temperature-dependent viscosity model to account for the non-Newtonian behaviour of lava; (iv) a transport equation for temperature including thermal exchanges with the environment. These features place the model within the category of 2.5D models. The model's performance was rigorously tested against laboratory experiments and data from the 2014–2015 Pico do Fogo eruption, Cape Verde. Results demonstrate that the model accurately captures essential flow features, such as front advancement and cooling dynamics, even in complex topographies. The model's ability to produce accurate results in short execution times makes it a valuable tool for real-time hazard assessment and the creation of probabilistic hazard maps. Retrospective tests on the Fogo eruption demonstrate its potential for improving risk assessments during future eruptions, providing critical support for evacuation planning and civil protection strategies.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Lava flow hazard assessment at a frequently erupting, small island volcano using PyFlowGo: Manam Papua New Guinea

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Hazard assessments are key to mitigating the impact of effusive eruptions on local populations. They are particularly important for Small Island Developing States (SIDS) where populations[AC1] are in close proximity to eruptive centres. One example is Manam, a frequently erupting, 10 km wide volcanic island in Papua New Guinea. Historical effusions have occurred from the volcano's summit craters and vents on its upper flanks. Most have fed flows down the island's four principal valleys. However, at least five undated eruptions have produced satellite cones near the coast, indicating the potential also for low flank eruptions close to the island's settlements. In 2018-2019 lavas from the main summit crater threatened two villages resulting in their relocation. This has prompted a reassessment of lava hazard across the island. Here we present the results of a new hazard assessment using the thermo-rheological model PyFlowGo. We found that summit-fed flows channeled via the main valleys are unlikely to impact settlements directly, although high effusion rates could produce flows long enough to enter the sea and to create "laze" (lava haze) which could affect settlements across the island. We show that northeast valley lava flows are capable of inundating populated areas but that this requires either a change in the Main Crater morphology, a high effusion rate [AC2] or a new northeast valley flank vent. Our modelling reveals the highest threat is posed by satellite cone eruptions which have previously formed close to current settlements but the probability of such eruptions has yet to be established.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

Compare and Contrast: A user-friendly workflow for assessing and comparing lava flow models

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Numerical models are a powerful tool for forecasting the evolution and extent of lava flow fields. Thus, there are many different models available, each with its set of assumptions, numerical methods, governing equations, programming language, inputs, and outputs. This situation makes it difficult to compare and assess models, either against each other or against observations, which can lead to a limited ability to forecast and quantify uncertainty. We present a user-friendly workflow to set up, execute, and compare multiple lava flow models, all within a notebook hosted on a cloud-based server. We use examples from recent eruptions in Iceland and Hawai'i and new model assessment tools to evaluate and compare the fit of all model forecasts to observations. The workflow is included in the VICTOR platform, a new cyber-infrastructure for volcanology, and demonstrates the added value of using a unified and joint platform beyond individual open-code repositories.

Theme: 6. Hazard, Risk and Impact

Session 6.5: Lava flow hazard assessment: Monitoring, pre- and syn-eruptive modelling, and communication

Allocated presentation: Poster

From flow to furnace: Low viscosity of three-phase lavas measured at Kīlauea 2018 eruption conditions

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Melt composition, temperature, and crystallinity are three important characteristics driving lava rheology, which controls eruptive behavior. Traditional methods of measuring the viscosity of crystallizing basalts often yield different mineral characteristics to natural samples and are typically bubble-free. To quantify the viscosity of basalts inclusive of bubble and crystal cargo, we developed a new technique to measure high-temperature three-phase isothermal lava viscosity and applied it to samples from the 2018 eruption of Kīlauea. This new experimental technique begins at subliquidus temperatures, preserving original phenocrysts. A short experimental duration allows for the retention of most of the original bubble population (19%–31% vs. 36%) and replication of crystal textures from field samples, as documented in quenched post experiment samples. The observed rheological behavior in these experiments, conducted at syneruptive temperatures (1150–1105 °C) and strain rates (0.4–18 s^{-1}), should therefore be representative of the lava flows. We measured average viscosities of 116 Pa·s at 1150 °C to 167 Pa·s at 1115 °C (i.e., only 10%–25% higher than calculated liquid viscosities at those temperatures) and a maximum of 1800 Pa·s at 1105 °C. These results are much lower than viscosity measured in traditional bubble-free experiments, which plateaued at ~14,000 Pa·s at 1115 °C. Our results suggest the effect of bubbles in three-phase magmas may be greater than predicted by models based on two-phase bubbly liquids, and this effect must be included in realistic lava flow rheology models. The method proposed here supplies a framework for providing the necessary experimental constraints.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Talk [Invited]

Development of a health-relevant exposure index for volcanic emissions: example from the 2021 Tajogaite eruption, La Palma, Canary Islands

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Volcanic eruptions inject vast amounts of particles and gases into the atmosphere, which degrade the ambient air quality and impact soils, vegetation and water resources upon deposition. To study the direct and indirect consequences of these eruptive phenomena on human health, it is necessary to quantify what people are exposed to during volcanic eruptions. To achieve this goal, we have developed an exposure index accounting for the volcanic gas and particulate matter (PM) pollution in the ambient air and the deposition of volcanic products on the ground. We used the 3-month 2021 mafic eruption of Tajogaite on the island of La Palma, Canary Islands, as a case study. This eruption was characterized by emplacement of lava flows and production of tephra and gases in multiple sustained plumes. We analyzed the spatiotemporal variations in tephra sedimentation using a tephra collection network and satellite data, and in air quality using the Government of the Canary Islands regulatory monitoring network on island. We correlated peaks in tephra sedimentation and air quality and related them to the eruption dynamics at the vent and the atmospheric conditions. We mapped the cumulative mass of tephra deposited per unit area during the eruption around the island. We also quantified exceedances of WHO Air Quality Guidelines for PM10, PM2.5 and SO_2 and mapped their occurrences. These data allowed for construction of a spatialized exposure index accounting for multiple products of volcanic emissions that can be assigned to individuals based on geographic location and subsequently used in epidemiological studies.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Talk [Invited]

Active volcanism and nontuberculous mycobacteria lung disease: confounders and connections

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The microbial content of aerosolized volcanic ash and consequences to respiratory health have yet to be fully quantified. We were the first to report that freshly erupted ash from the 2018 Kīlauea eruption harbored pathogenic nontuberculous mycobacteria (NTM). NTM are opportunistic pathogens that cause pulmonary disease (PD) in people with pre-existing lung conditions (*e.g.* cystic fibrosis, bronchiectasis). NTMPD prevalence shows geographic disparities, suggesting potential links with aerosol inhalation and volcanic exposures. Narrowly, we hypothesize that volcanic ash inhalation promotes NTMPD via pro-inflammatory pathway stimulation, including the inflammasome in lung cells. Broadly, we suspect NTMPD prevalence correlates with global volcanism and volcanogenic element enrichments in water supplies. Data compilation shows countries with active volcanism are significantly more likely to show high NTMPD cases. Using our Kīlauea ash (KA) sample and KA-derived NTM, we discovered the ability of airway epithelial cells and lung airway organoids to control KA-derived NTM infection did not differ with KA exposure and KA did not cause cell cytotoxicity. Thus, mafic ash exposure alone is not the sole driver for NTMPD. It's possible that dust's surface functional groups influence NTM viability. Using allophane and gibbsite, NTM growth was respectively unaffected or significantly reduced. Other exposures may increase NTMPD risk. For example, mafic volcanic products are enriched in metals such as vanadium. Using ICP-MS, we correlated areas with higher tapwater vanadium to higher NTMPD prevalence in the NTMPD hotspot of Hawai'i. Future work includes targeting transcriptomic responses of NTM and KA-exposed lung cells to mineral dusts using nebulized exposures.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Talk

Bridging the gap: Addressing volcanic agricultural risk management challenges across multi-scale governance authorities and stakeholders

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Disaster risk management decisions are often made across multiple scales of government authorities, statutory agencies and community groups. This multi-scalar approach leads to challenges where multiple decision-makers are operating at national, regional and local scales; potentially with different aims, approaches, and misaligned expectations of other risk management actors, especially those operating at different spatial scales. New Zealand's agricultural sector is highly exposed to volcanic processes, exacerbated by increasing reliance on critical infrastructure and technology, distended supply chains and the effects of climate change. Volcanic risk management for the agricultural sector in New Zealand involves national, regional, and local government, businesses, NGOs, communities, professionals, and landowners in planning, response and recovery. Workshops in Taranaki (regional-scale) and Pōneke-Wellington (national/strategic-scale) found a disconnect between regional and national scale groups, where expectations for the provision of advice and resourcing, including financial support, did not align. We identified a need for more specific guidance and the pre-event identification of clear coordination pathways between stakeholders. Any major eruption will lead to concerns about food quality and safety from domestic and international markets, but very few primary producers have food safety plans ready for immediate deployment. In response to this, we developed an eruption scenario with New Zealand Food Safety for use during a food safety exercise. This exercise coalesced efforts to create a post-event tephra

sampling plan in partnership with commercial laboratories, the development of a food safety risk management plan appropriate for use after a volcanic eruption, and bespoke advice for food producers.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

Assessing the air quality hazards of chronic exposures to volcanic gases and particulate matter on Montserrat, Eastern Caribbean

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Soufrière Hills volcano has not erupted ash since 2011 yet emits roughly 440 tonnes per day of sulphur dioxide (SO_2) with recent spikes reaching up to 1000 tonnes per day. Depending on meteorological conditions, local communities on Montserrat may be exposed to variable and potentially poor air quality through high concentrations of SO_2 and other key species such as $PM_{2.5}$. As SO_2 is known to cause health problems even in low concentrations and PM classified as a carcinogen, monitoring of these pollutants is needed to facilitate assessment of the chronic health risks of volcanic emissions. This project aims to conduct the first calibrated, high temporal resolution assessment of the concentrations and dispersion of SO_2 and PM on Montserrat to advise local agencies on ambient air quality levels and allow for risk assessment, reviewing the case for long term air quality monitoring. Discussions with government officials and local scientists at the Montserrat Volcano Observatory (MVO) were used to co-develop this research. During 2023 & 2024 field campaigns, a 13 site SO_2 and PM sensor network was installed to collect data for 2 years. Here, we present its calibrated, high-resolution time series data, as well as compositional analyses and imaging of filter-pack data.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

Chronic volcanic ash exposure alters male fertility mediated by oxidative stress-related isotopic variations and hepatic alterations

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Volcanic eruptions release a range of sizes of particles that can affect the health of communities up to thousands of kilometers away from the volcano. Many years after an eruption, volcanic ash resuspension can exacerbate the health impact of primary eruptive events. So far, our global understanding of the health effects triggered by chronic exposure to resuspended volcanic particles at the whole-body scale is extremely limited. In a recent study [1], we demonstrated that mice chronically exposed to metal-rich volcanic ash deposits present an organ-specific and isotopically-typified metallome deregulations associated with pathophysiological changes. These deregulations significantly impact the reproductive functions as evidenced by spermatogenesis alteration. To further assess the underlying mechanisms accounting for this ash-related infertility disorders, chemical (major and trace element concentrations) and Cu-Zn-Fe isotope measurements coupled to metabolomic, proteomic and transcriptomic analyses were measured in organs and biological fluids collected on mice (C57BL/6) exposed over 2 months to volcanic ash. We found that exposed mice are characterized by (i) high oxidative stress status correlating with isotopic variations of redox-sensitive elements and (ii) hepatic alterations, marked by lipid accumulation and circulating bile acids overload, that both might exacerbate testicular defects. Altogether, these results demonstrate that prolonged exposure to metal-rich ash induces testicular toxicity likely mediated by oxidative stress and/or hepatic dysfunctions and suggest that redox-sensitive isotope tools might help identifying early signs of oxidative stress. [1] Sauzéat et al., STE, 829, 154383 (2022)

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

Multiple impacts caused by CO2 diffusely released from soils in volcanic environments

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CO_2 diffusely released from soils in volcanic areas may affect infrastructures, environment, fauna and humans during eruptive and quiet periods of activity. A recent review of the literature highlighted lethal air CO_2 concentrations (> 100 000 ppm) in different volcanic systems, such as Azores (Portugal), Canary (Spain) and Aeolian Islands, Colli Albani (Italy), Massif Central (France), Methana (Greece), Mammoth Mountain (USA), Rotorua (New Zealand), Nyamulagira and Nyiragongo (DR Congo) volcanoes. When population is exposed, reported symptoms include nausea, vomiting, dizziness, tiredness, increasing breathing rate, loss of consciousness, which are essentially associated with the reduced oxygenation. Human and animal casualties have been also reported. In the Azores archipelago, several villages are located in high soil CO_2 emission zones resulting in high indoor CO_2, depending also on the edifices vulnerability. Values higher than 200 000 ppm have been measured in some buildings in the last 20 years, which are mainly explained by the high CO_2 emission and the effect of meteorological parameters on the gas fluxes. In anomalous thermal zones, indoor CO_2 may rise to the upper floors of the buildings and reach higher concentrations than at the expected ground level. In some of the degassing areas, high indoor ^{222}Rn and H_2S concentrations highlight the multi-gas permanent hazard. These hazardous concentrations detected in quiescent and extinct volcanoes suggest that the gas is transported to the surface through extensional tectonic structures. Bared soils and altered vegetation are also some of the impacts reported in the Azorean degassing areas.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

Integrated Analysis of Volcanic Ash Morphology and its Impact on Respiratory Health: Insights from the 2021 Tajogaite Eruption

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Volcanic eruptions pose health risks dominantly through gas and ash emissions, with respiratory effects being a primary concern for exposed populations. By combining confocal laser microscopy, spectroscopic analysis, and biological experiments to characterize the 3D morphology and chemical composition of respirable volcanic ash particles (PM10 and PM2.5), insights into potential toxicity mechanisms can be gained. Analysis of silicate ash from the 2021 Tajogaite eruption (La Palma, Spain) revealed angular particles with distinctive sharp surface features and salts adhering to their surfaces. Experiments *in vitro* with human primary bronchial epithelial cells demonstrated enhanced pneumococcal bacterial adhesion in ash-exposed cells compared to control cells, indicating that fine volcanic ash exposure may increase susceptibility to respiratory infections. Pneumococcal adhesion also increases in a dose-dependent manner: more ash exposure carries higher infection possibility. The smallest particles, which can be remobilized long after eruption cessation, therefore present an ongoing hazard. This integrated analytical approach provides insights into respiratory health risks in populations exposed to volcanic ash, with particular relevance for regions like the Canary Islands where communities face ongoing exposure to both volcanic ash and other inorganic particulates. The methodology presents a rapid and effective framework for assessing health hazards associated with respirable volcanic particles, enabling better risk assessment and mitigation strategies.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

Biological effects of co-exposure to Tajogaite volcano (La Palma, Spain) ash and sulphur dioxide gas in human lung cells

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Volcanic emissions are an important source of natural air pollutants, including, but not limited to, sulphur dioxide (SO_2) gas and fine particulate matter, that can degrade air quality in populated areas. Short-term exposure to these pollutants has been associated with acute respiratory symptoms, such as irritation and cough. However, the potential lung injury from combined exposure to multiple volcanic pollutants is still poorly understood, as biological investigations to date have focused primarily on volcanic ash. In this study, we investigated the biological impact of acute co-exposure to volcanic ash and SO_2 gas on human alveolar epithelial cells (A549) to evaluate whether combined exposure poses a greater hazard than inhaling them separately. In the experiments, we used sub-10 μm ash from Tajogaite volcano, representative of resuspension material. We exposed A549 cells cultured at the air-liquid interface to ash (100 μg/cm^2) and SO_2 gas (50 ppm for 1 h, 2 h or 3 h), individually and concomitantly, using a sophisticated cell exposure system (CelTox Sampler). Subsequently, we assessed cellular responses, including cytotoxicity (LDH release) and release of pro-inflammatory markers (IL-6, IL-8 and MCP-1, at gene and protein levels). The results indicate that exposure to volcanic ash alone had limited impact on A549 cells. However, prolonged SO_2 exposure appeared to impair the cellular response, and co-exposures increased the release of pro-inflammatory markers. These findings suggest that combined exposures to volcanic pollutants could potentially affect the normal inflammatory response. These data could also help explain responses not necessarily captured by single-pollutant experiments.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

Role of pristine and remobilised tephra in coastal manganese cycles and its impact on coral reef physiology

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On April 9th the La Soufrière volcano on St. Vincent erupted, ejecting copious amounts of ash, and impacting surrounding coral reefs. Upon contact with seawater, ash surface adhering metal salts and acids rapidly dissolve, releasing essential trace metals such as manganese (Mn), which is reported to enhance coral photosynthesis. This study aimed to quantify Mn leaching from four different tephra types (marine tephra, riverbank tephra, fine-grained summit pyroclastics, and pristine ash) deposited during the eruption and to assess its effect on Mn uptake and photosynthetic efficiency in the coral *Stylophora pistillata*. A three-week coral culture experiment was performed at the Centre Scientifique de Monaco using 24 beakers (1L), containing either tephra with coral microcolonies or tephra alone. Tephra (1g) was added five times per week, and Mn concentrations in seawater were sampled weekly and measured using inductively coupled plasma mass spectrometry (ICP-MS). The photosynthetic efficiency of the coral was monitored by measuring the effective quantum yield of PSII. All tephra types released substantial amounts of Mn into seawater, with pristine ash leaching the most (12-14 ppb), compared to altered deposits (0.35 – 5.4 ppb). Despite negligible coral Mn uptake, an increase in photosynthetic efficiency was observed, particularly at Mn concentrations up to 4 ppb, beyond which no further benefits were detected. This study provides the first evidence that tephra, regardless of depositional age or environment, can enhance coral photophysiology. These findings underscore the ecological importance of volcanic ash in marine ecosystems, suggesting subaerial volcanism may support coral photosynthesis via Mn-mediated pathways.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

How does volcanic mercury impact the environment? A time-integrated analysis of mercury dispersion and accumulation in plants, insects, and soils at Mt Etna (Italy)

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Active volcanoes emit metals such as mercury with potentially negative/harmful impacts on the health of communities living in proximity. Our work aimed to determine: a) the level of accumulation and distribution of mercury in the environment close to the emission source (up to 13 km), and b) its temporal storage in bioaccumulators. We have investigated the nature of mercury at the end of 2020–2022 eruptive activity and prior to the new eruptive cycle starting on July 4th, 2024 of Mt Etna (Italy), which is the largest volcano in Europe with >1M people living in its shadow, and one of the greatest emitters of mercury in the world. We conducted laboratory analysis of total mercury and methylmercury concentrations in chestnut leaves, insects (ladybugs and ground beetles), and soils (from tephra-devoid surface down to ~20-cm depth), which are putative prime accumulators of mercury in the environment, at elevations ranging from 720 to 2867 m a.s.l. and at distances from the Southeast Crater volcanic vent ranging from 0.9 to 12.5 km away. Our data showed that mercury accumulated most in the first ~5 cm-deep soil (2 to 36 ng/g) and in ground beetles (10 to 156 ng/g, which is 2 to 60 times higher than that of ladybugs). Their main distribution follows the eastward / southeastward dispersion of gas and tephra from paroxysms at Mt Etna. We plan to correlate mercury accumulation and dispersion with soil mineralogy, organic concentration, eruption intensity and quiescence.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

The toxic effect of volcanic soil nanoparticules, imogolite and halloysite, nanoparticles on macrophages

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Several diseases can result from excessive exposure to (nano)particles, including podoconiosis, the second most common cause of tropical lympheodemia. This “medical geology” disease is caused by childhood exposure to irritant particles, such as imogolite and halloysite nanotubes, derived from volcanic glass and ash particles, found in volcanic soil, and accumulation of such particles in the legs and feet lymph nodes of poor bare foot farmers. This neglected tropical disease currently affects 4 million people worldwide. Our study explores the cell viability of NR8383 macrophages after exposure to different concentrations of imogolite and halloysite nanotubes. To achieve our objectives, NR8383 macrophage cells were exposed to imogolite and halloysite nanotubes at various concentrations for durations of 1, 4, 8, 12, and 24 hours. The macrophage viability as a function of particle concentration is explore using MTT test at a wavelength of 550 nm, in a dose response way. Macrophages appear to degrade imogolite nanotubes. In contrast, for halloysite, we noted a progressive decrease in cell viability as the concentration increased, indicating the toxic effect of halloysite on macrophages. These two nanotubes may activate distinct biological pathways which will be discussed, i.e. different cellular toxicity responses to low and high levels of nanotube.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

Surface analyses of the ash from the 2021 Tajogaite eruption, La Palma, reveals compositional diversity and complex formation pathways of fluoride-bearing compounds

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The presence of soluble fluoride in volcanic ash fallout often raises environmental and health concerns. Numerous studies have reported notable concentrations of fluoride in ash leachates, sparking diverse interpretations regarding the composition and formation mechanisms of fluoride-bearing compounds in volcanic ash and their associated hazards. The 2021 eruption of Volcán de Tajogaite, Cumbre Vieja, La Palma, provided a unique opportunity to investigate the occurrence of fluoride-bearing compounds on ash surfaces over an 85-day period of ash emissions. This study presents detailed surface analyses (using high-resolution SEM-EDX and XPS) of fresh ash samples representative of the entire duration of the eruption. Our findings reveal a remarkable diversity in the composition of fluoride-bearing compounds on the ash particles. Both soluble (alkaline and alkaline-earth metal salts) and poorly-soluble fluoride (hexafluoroaluminates) species were identified, with their relative abundances varying significantly across the analysed samples. We suggest that this complexity primarily reflects the temperature conditions governing in-plume interactions between the ash surface and the magmatic gas phase. Additionally, the island setting of the eruption likely contributed to the chemical diversity through the incorporation of marine aerosols into the hot volcanic gas-ash mixture. Our conclusions diverge from prior interpretations of the leachate compositions of Tajogaite ash, with significant implications for inferring the potential environmental and health hazards posed by the ash deposits on La Palma island.

Theme: 6. Hazard, Risk and Impact

Session 6.6: Life in volcanic environments: Human and Environmental Health impacts of volcanogenic contaminants

Allocated presentation: Poster

Origins of a public health hazard: Crystalline silica in respirable volcanic ash from the May 18, 1980 Mount St Helens eruption

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Abundant cristobalite, a potentially toxic form of crystalline silica, in respirable volcanic ash was an unforeseen hazard prior to the 1980 eruption of Mount St Helens. Its discovery prompted widespread concern of ash inhalation owing to the known hazard of respirable crystalline silica in occupational settings. Here, we revisit the respirable cristobalite hazard in ash from the 1980 eruption through retrospective analysis of variations in deposit characteristics. Leading up to the May 18 eruption, cristobalite crystallized in the cryptodome through preferential devitrification of 'black' dacite compared to 'grey'. This bimodality aligns with assertions that the grey dacite was sufficiently ductile to undergo secondary vesiculation upon depressurization. Cristobalite is also present as a secondary mineral in samples of the pre-existing edifice. Consequently, cristobalite would be concentrated in ash derived from fragmentation of the cryptodome and edifice, produced in the early blast phase of the eruption. The proportion of respirable ash in the fall deposit increases with downwind distance from vent, following the general trend of deposits fining with distance. However, there is pronounced crosswind asymmetry in the particle size distributions and textural componentry: towards the north, enrichment in fine ash from the early explosive phase; towards the south, coarser grain sizes and particles dominantly from the late, high-intensity Plinian phase. These retrospective constraints on the origin and distribution of cristobalite in the 1980 tephra advance our spatiotemporal understanding of ash hazards during eruptions and can inform syn-eruptive hazard assessments and sampling strategies during future eruptions, at Mount St Helens and globally.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Talk [Invited]

Probabilistic volcanic hazard and impact assessment of the Auckland Volcanic Field, Aotearoa New Zealand

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Volcanic eruptions can be particularly complex and/or enduring events capable of producing multiple hazards simultaneously and/or consecutively, causing compounding impacts on society. Correspondingly comprehensive volcanic risk assessments are therefore required to inform appropriate disaster risk and resilience strategies. We present a conceptual framework for probabilistic volcanic multi-hazard impact assessments. We develop this framework within a case study of the Auckland Volcanic Field (AVF), Aotearoa New Zealand, utilising existing eruption scenarios. This probabilistic approach will reduce the potential for bias that scenarios inevitably suffer from, and allow easier comparison with other similarly assessed risks (e.g. seismic). We use existing dynamic eruption scenarios for the AVF, which include multiple volcanic hazards and transitions in eruptive style, for which we have relative likelihoods at every location in the field based on the matching of environmental factors and eruption styles. We combine these with detailed location-specific modelling of hazard phenomena to produce pseudo-probabilistic hazard and impact estimates. We present results for site-specific probability of various hazard impacts, including combinations of hazard impacts arising from the entire suite of scenarios, weighted by likelihood of occurrence. The results of this case study will inform short- to long-term planning and mitigative strategies in Tāmaki Makaurau Auckland city, including for nationally significant sectors. The framework and case study will be incorporated as a probabilistic volcanic multi-hazard impact module for broader national volcanic risk assessment and management frameworks.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Talk [Invited]

Are cities becoming increasingly threatened by volcanic hazards?

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City expansion near volcanoes exposes dense concentrations of people, buildings, and infrastructure to volcanic hazards. Identifying key cities at risk and quantifying the rates of city population expansion on different scales can inform targeted research, mitigation, and land-use planning efforts. We rank 1,106 cities globally based on their exposure within 100 km to 596 Holocene volcanoes, considering population counts, proximity to volcanoes, and the number of nearby volcanoes. Notably, 50% of people currently living within 100 km of a volcano are in cities, with some exposed to multiple volcanoes. Over 8 million people in Bandung, Indonesia, live within 30 km of up to 12 volcanoes. Building on these rankings, we assess urban expansion and population growth between 1975 and 2020, using data at 5-year intervals and future projections between 2030 and 2070 at 10-year intervals. We show that, on average, city margins are spreading towards volcanoes. We also show the rate of increase in city population density towards volcanoes. However, for some countries, such as El Salvador, Japan, or the Philippines, where >70% of land is exposed to volcanic hazards, there are limits on the availability of safer areas for expansion. Using city case studies, we assess directions of city expansion and relate these to potential volcanic flow directions and wind directions to identify critical areas for more localised assessment and mitigation efforts. Our research provides a framework for global and localised assessment of spatio-temporal city population trends, highlighting the increased exposure and need for targeted mitigation efforts.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Talk

Quantifying cascading impacts through road network analysis in an insular volcanic setting: the 2021 Tajogaite eruption of La Palma Island (Spain)

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Post-event impact assessments (PEIA) are fundamental to elucidate the drivers of disasters and better anticipate the impacts from future events. The 2021 Tajogaite eruption of Cumbre Vieja (La Palma, Spain) demonstrated the various orders of impact due to compound volcanic products (i.e., lava, tephra, gas) affecting a highly interconnected and low redundant infrastructure, typical of insular environments. Using a forensic approach, we discretise the causal order of cascading impacts, from physical damage (first order) to loss of functionality of the road network (second order) and subsequent systemic disruption of emergency management and socio-economic sectors (third order). Based on graph theory, we apply a comprehensive road network analysis to quantify the loss of functionality and resulting effects on driving time syn- and post-eruption. Loss of functionality is based on the spatiotemporal evolution of connectivity using centrality indicators, calculated for all road segments. The consequences on dependent systems are expressed in terms of increased driving time between target locations for emergency (evacuation), public health (hospital), agriculture (crops-market), and education (schools). Graph indicators are objective measures of road system performance both during (disturbing and degraded states) and after the eruption (restorative phase), when two new roads where rapidly built to reconnect the northwest and southwest of La Palma island. This study demonstrates how network analyses, informed by comprehensive PEIA, can accurately capture complex systemic disturbances of infrastructures, thus highlighting its potential for risk assessments.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Talk

Forecasting tephra impacts during the 2024 unrest at Awu volcano, North Sulawesi, Indonesia

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After 20 years of repose, Awu volcano in Indonesia began a period of unrest in May 2022, which intensified in 2024 with increasing seismic activity and inflationary deformation. With five large (VEI ≥3) eruptions in the past ~300 years, and an island setting that concentrates populations within 40 km of the summit, Awu poses a significant threat to exposed communities. We evaluated the potential impacts of tephra fallout and large clasts from a VEI 4 eruption, the most likely scenario given the current unrest. Tephra, the most widespread and common volcanic hazard, can cause a range of impacts that include fatalities from large clasts near the vent to damage buildings and infrastructure tens of kilometers away. We focused on buildings, given their critical role in providing shelter, supporting livelihoods and facilitating recovery. Forecasting eruption impacts requires integrated assessment of hazards, exposure, and vulnerability, each with unique challenges. To address these, we developed tailored methods for Awu volcano. We supplemented Awu's eruption history with data from analogue volcanoes to conduct probabilistic hazard assessment. This was combined with exposure information obtained from satellite optical imagery, where building typologies were classified from the pixel intensities. To derive vulnerability information for the building typologies present we employed Bayesian inference to integrate existing vulnerability models and propagate uncertainty in the analysis. The resulting forecasted impacts provide valuable planning information during this unrest stage, giving a foundation for targeted risk mitigation strategies that can contribute towards improving the resilience of communities living around the volcano.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Talk

Combining agricultural production sensitivity and farming practices paves the way for comprehensive volcanic risk analysis

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Tephra fall during explosive eruptions poses a serious risk to agriculture, jeopardizing the livelihoods of millions of people who live close to active volcanoes. Few studies have investigated quantitatively the impact of tephra on agriculture. These typically use a "dose-response" approach, attributing an expected crop yield loss to a given tephra thickness. However, agriculture consists of combinations of crop and livestock productions and practices that interact dynamically. Therefore, the impact of tephra on agriculture cannot simply be reduced to the sum of its impacts on individual productions. We argue that a systemic approach is critical for accurately assessing agriculture's sensitivity to tephra fallout. Based on semi-structured interviews conducted in 26 farms in the Philippines and Ecuador, we developed "sensitivity matrices" for various crops and farm animals exposed to tephra. This approach expands on the "dose-response" model by incorporating a refined agronomical perspective, assigning expected yield loss based on phenological and physiological characteristics as well as development stages. We then identified a range of farm archetypes, each representing a different combination of crop and livestock productions in varying interactions. Using the sensitivity matrices, we calculated the overall expected losses for these farms when exposed to tephra throughout the year. Our findings reveal the importance of considering farm diversity and the degree of interaction between crops and livestock practices. They also highlight complex sensitivity patterns influenced not only by the diversity of agricultural productions but also by their physiological cycles, interactions within the farming system and degree of dependency to external inputs.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Talk

The complex and often contradictory realities of the red zone; three cases around Fuego Volcano, Guatemala.

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Red Zones, “exclusion zones”, or areas deemed by state authorities as being “uninhabitable” around volcanoes remain home to many people. While these demarcated spaces are no-go areas in geological or disaster risk management perspectives, the reality and immediate needs of those who inhabit them is more complex. With no viable alternative living spaces provided by the government or municipalities, people continue to live in these areas. The sustainability of livelihoods is a key driver for remaining despite the threat of volcanic activity. This work will present learnings from a transdisciplinary project working with people from three communities around Fuego volcano, as well INSIVUMEH and CONRED the Guatemalan civil protection organisation. We follow some of the long-term impacts in the communities of La Trinidad, Las Palmas, and El Rodeo, two of which are formally exclusion zones, through ethnographic and practical action work with community leaders. In these communities, people left for periods of time, returning when the immediate danger was past, and/or life elsewhere became too difficult. Risk assessment decisions taken after the Fuego 2018 eruption have led to, in many cases, problematic and unintended outcomes. The results of work on the impact of evacuations, resettlement, and fragmented communities as well assessments of the level volcanic hazard are now being brought together to inform a review of the risk assessment procedures for managing risk around this persistently active volcano.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Fatalities associated with Pyroclastic Density Currents: Insights from an updated global dataset

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Pyroclastic density currents (PDCs) are considered one of the most fatal volcanic hazards, with recent disasters in Merapi (2010), Sinabung (2014-2016), Fuego (2018), and Semeru (2021) emphasising the continued threat that PDCs pose to human life. Due to high uncertainty in PDC behaviour, quantifying PDC hazards remains a challenge in disaster risk reduction, making efforts to minimise human exposure and vulnerability essential. Analysis of data on fatalities from past PDC events can improve our understanding of PDC impacts across different flow types, magnitudes, and volcanic contexts. In particular, the spatial relationships between flow paths, population locations and evacuations routes influence the outcomes. This study aims to enrich and update data on PDC-related fatalities by conducting a comprehensive review of published literature, maps, eruption records, news sources, and official press releases to build a detailed dataset of PDC characteristics and their impacts on human life. Preliminary findings indicate that between 1500 and 2023, at least 93 volcanic eruptions resulted in fatalities related to PDCs. A third of these incidents (34) occurred before 1900, with the remaining incidents occurring in the past century. Among these 93 incidents, 65 were located in East-Southeast Asia and Oceania. The most lethal event was Mount Pelée in May 1902, where at least 28,000 fatalities occurred, while, the August 1883 Krakatau PDC was notable for the distance travelled with fatalities recorded up to 47 km from the eruption point. Other key conclusions from the preliminary study will be presented.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Dispersion of SO2 during the 2021 Tajogaite eruption, la Palma and associated health-relevant population exposure assessment

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The 86-day-long Tajogaite eruption, la Palma (2021) caused widespread disruption. The eruption emitted around 203x106 m^3 of basaltic lava, and. approximately 1.6 Mt of SO_2. Whereas much of this gas was injected into the upper atmosphere, the numerous and voluminous lava flows also introduced SO_2 at much lower altitudes where it could be dispersed by the wind. This highly noxious gas therefore had the potential to be transported to towns and villages over considerable periods. SO_2 is hazardous to human health and the World Health Organisation has recommended that the 24-hour mean ambient air concentration should not exceed 40 µg/m^3. It is therefore important to quantify the concentrations and exposure durations of the populations in order to anticipate and combat future health issues. Whilst air-quality stations were installed before and during the eruption, the data from these instruments are point measurements and the time-varying global distribution of gas would provide highly sought-after information. We provide an estimation by performing numerical simulations of the dispersion of SO2 from (mainly) lava flows using the DISGAS software. Source SO_2 fluxes were estimated using the PlumeTraj software using TROPOMI data. Wind data at near-ground level were obtained from several weather stations around La Palma and combined with atmospheric information from the ERA5 climate model reanalysis provided by Copernicus. We show preliminary results of how SO_2 concentrations vary over time for a variety of locations, which compare well with the air-quality data.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

How fit-for-purpose are volcanic physical vulnerability models at predicting impacts in diverse risk contexts?

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Our understanding of physical vulnerability to volcanic hazards is underpinned by observations from very few eruptions. This is in part due to the scarcity of eruptions when compared to other geological hazards, but is exacerbated by uncoordinated post-event data collection, processing and sharing procedures. Vulnerability models are crucial to anticipate and forecast impacts to inform volcanic risk management, however there are limited frameworks to validate and update vulnerability models with post-event impact data, and limited consideration of the suitability of available vulnerability models to global contexts. The 2021 Tajogaite eruption of La Palma, Canary Islands, Spain, impacted surrounding assets, economic activities and communities. Using post-event impact data collected during field campaigns conducted by the University of Geneva, we demonstrate that retrospective impact assessment is highly misaligned with the observed impacts, with some models highly overestimating the damage and disruption witnessed during the event. Using the case study of the 2021 eruption of Tajogaite, we provide some recommendations for the development, curation and application of volcanic physical vulnerability models, addressing the following questions: (1) Do risk contexts necessitate the development of unique suites of physical vulnerability models? (2) How can we determine the suitability of established models to other volcanic risk contexts? (3) What data collection, processing and sharing procedures should be in place to enhance the accuracy and therefore useability of models? And (4) How do we characterise and quantify the limitations and uncertainties of available vulnerability models for impact and risk assessment applications?

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Can we account for human displacement in volcanic risk analyses?

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The Internal Displacement Monitoring Centre (IDMC) estimates that 9.8 million movements of people were triggered by geophysical hazards between 2019 and 2023, including 1.3 million displacements caused by volcanic eruptions. Beyond being one of the least reported impacts of sudden-onset disasters, the potential for displacement is rarely recognised and almost never accounted for in volcanic risk analyses. Displacement bears a cost to inviduals and local communities up to scale of the country or the international communities, thus highlighting the need to account for disaster-related displacement into disaster risk reduction. We present here the foundation of a new methodology to better capture and predict potential displacements caused by volcanic activity. By using Guatemala as a case study, we explore how modern geospatial analysis, hazard modelling techniques, exposure datasets and vulnerability models can help estimating displacement caused by a combination of loss of housing, means of livelihood and access to essential services. This work paves the way to investigate a previously overlooked aspect of volcanic risk and provides a more comprehensive representation of the disaster risk landscape for future eruptions.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Volcanic Risk Ranking of the Southern Volcanic Zone of the Andes using open data

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This work presents a new risk ranking (VRR) methodology applied to the volcanoes of the Southern Volcanic Zone of the Andes (SVZA), located between Chile and Argentina. The new VRR takes advantage of a new framework for constructing open-source regional databases considering multiple categories of critical assets in a multi-hazard volcanic context. Sources and data quality are assessed using a scoring system and a qualitative scale. The methodology considers four risk factors, i.e., hazard, exposure, vulnerability, and resilience, and can be achieved using a combination of 2, 3, and 4 factors depending on the study's overall objective. In fact, the application of the new VRR yields various outcomes tailored to decision-makers needs. It provides three levels of analysis: 1) the volcanic threat accounting for the hazard and exposure factors (2-factor VRR), 2) the relative volcanic risk by considering the hazard, exposure, and vulnerability factors (3-factor VRR), and 3) the degree of resilience existing around a volcano testing all four factors (4-factor VRR). The resilience factor evaluates the presence or absence of mitigation and response measures around a volcano. Therefore, the 4-factor VRR highlights volcanoes with measures promoting preparedness and strengthening capacities and identifies those that might need more attention. This VRR allows the identification of the highest-threat volcano, the relatively highest-risk volcano, and the volcano requiring the development of mitigation strategies at regional scale independently of borders.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Te Awe Mapara, towards a National Volcano Hazard Model under climatic changes

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Volcanic eruptions pose an uncalculated risk to New Zealand, from loss of lives and threats to tourist and recreational industries, to the potentially $10 billion consequences of an Auckland eruption. The 2019 Whakaari disaster emphasised critical gaps in the understanding of volcanic hazard characteristics, and the lack of hazard-based forecasts for informed risk management. At larger scales, mitigating potential losses requires well-informed land use planning policies, underpinned by robust climate-cognisant assessments of future volcanic hazard impacts to reduce uncertainty. Te Awe Mapara is a new five-year research programme seeking to create a step change from status-quo eruption onset forecasting to forecasting hazard and impact, by unravelling the complex interplay in understanding volcanic eruption source parameters (e.g., size, style, timings), hazard dynamics and climate-driven environmental effects. Conceptualising and quantifying environmental factors in these forecasts is vital to future-proof the resulting models. Assessment of new monitoring streams incorporating environmental indicators will underpin eventual operationalisation through future Tangata tiaki volcano observatories co-developed with Maori partners. New multi-hazard/multi-impact vulnerability and impact models will eventually allow for volcanic risk and uncertainty quantification at all levels from life-safety to national economy. The benefits will include risk quantification (reduction in uncertainty leading to more robust decision making, and more accurate pricing in insurance, including risk-sharing options), risk mitigation (more resilient infrastructure siting, improved contingency and evacuation planning) and risk adaptation (fit-for-purpose unified response during unrest, eruption and quiescence; increased resilience to future volcanic hazards under climatic changes).

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Assessing volcanic warning systems within a complex multi-hazard environment – a case study from Samoa

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Samoa is a small island developing State in the central South Pacific, with mountainous volcanic topography and a population of around 205,000 living mostly near the coasts of two main islands. The country is exposed to many natural hazards, including tropical cyclones, volcanic eruptions, tsunamis, floods, earthquakes, landslides and forest fires. During the past six years, Samoa has made considerable efforts to upgrade its multi-hazard early warning system (MHEWS) governance, policy and procedures, and intends to continue this work with the support of partners and donors. To invest in improving this MHEWS requires an objective understanding of system vulnerabilities from an integrated, multi-disciplinary risk-based perspective that explicitly includes meteorological and geohazard events. Some past external assessments in Samoa and elsewhere have neglected to include geohazard components, perhaps because of a focus on climate-related issues. During early 2024, we adapted work from the World Meteorological Organization's HIWeather Value Chain project to produce an MHEWS warning chain assessment matrix, with hazards listed in priority order and the vulnerabilities of different capabilities and outputs along the chain colour-coded according to the level of concern. The results highlighted critical points of MHEWS failure in unexpected places along the warning chain, as well as many areas where investment, integration, and other system improvements are needed. This matrix was then used to inform a series of urgent, strategic and operational recommendations for MHEWS improvement, and including for volcanic hazards.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Development of a pedestrian evacuation model and application to two active volcanoes in Indonesia

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Pedestrian evacuation is an important component of risk reduction strategies in proximal areas of active volcanoes, especially for touristic volcanoes associated with short-warning eruption styles. Amongst available strategies for developing and optimizing evacuation plans, Least Cost Distance (LCD) modeling has been widely applied to estimate pedestrian evacuation times for natural hazard events and can be effectively adapted for use in volcanic eruption scenarios. Its simplicity – both for initialization and interpretation – makes it suitable for providing first-order insights into exposure management plans for hikers before and during a crisis. We introduce an open-source, Python-based LCD model designed to estimate evacuation times to safe zones from volcanic hazards. The methodology is demonstrated through case studies of Mt. Awu and Mt. Marapi in Indonesia. For Mt Awu, we developed a purely magmatic eruption scenario and used a dedicated plume model to estimate the spatial distribution of probabilities of occurrence of lapilli with kinetic energies >30 J (i.e., threshold for skull fractures). For Mt Marapi, we developed an eruption scenario based on the phreatic phase of the Dec 2023 eruption. Since no model accurately captures tephra dispersal from such plumes, we use a radius-based approach. The proposed methodology allows for a transparent and easily reproducible analysis of the optimal evacuation routes in proximal areas which, when put in perspective of the warning time inferred from dedicated monitoring facilities available at specific volcanoes, can provide an efficient evidence-base for the prioritization and implementation of risk-reduction measures.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Volcanic Hazard Assessment of Paroxysms at Stromboli (Italy) with Uncertainty Quantification: Deposit-derived Pyroclastic Density Currents

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Stromboli volcano (Italy) features persistent explosive activity and occasional paroxysms from the craters located at ≈750 m atop Sciara del Fuoco, a horseshoe-shaped depression on the NW flank, and at ≈2 km from the two villages along the coast. Deposit-derived pyroclastic density currents (PDCs) arise from the gravitational instability of eruptive deposits at elevated temperatures. At Stromboli, these flows can occur outside Sciara del Fuoco during the paroxysms, and pose a significant additional risk to both residents and those ascending volcanic slopes, due to their high mobility. Notable historical examples include PDCs generated during the 1930 and 1944 paroxysms, which affected both inhabited and uninhabited areas. Similar phenomena have been documented on other mafic to intermediate volcanoes around the world, often with devastating consequences. By using Markov chain models, we reproduced clustering in paroxysmal events, and quantified average probabilities at 8.6% and 49% of one or more deposit-derived PDC occurring outside Sciara del Fuoco in the next 10 and 50 years, respectively. We estimated a 90% confidence interval of the PDC probability conditional on a paroxysm, identifying the occurrence rate as one of the key uncertainties of this hazard. This study develops probabilistic hazard maps for Stromboli's deposit-derived PDCs, conditional on paroxysms. Using historical data, field observations, and depth-averaged flow modeling, Monte Carlo simulations were employed to account for uncertainties in source area, thickness, and dissipation parameters. Application to the 1930 event shows that the model can reproduce the main flow observables from field evidence and historical chronicles.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Volcano mass-wasting and volcanic processes' risk assessment using Borromean Rings and Fuzzy Logic Systems

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Mass movements are natural processes which have been tailored the Earth's landscape throughout geological times. In volcanic environments, along with floods and thunderstorms, they are concerning threats in the daily lives of local inhabitants rather than volcanic eruptions in themselves. However, traditionally the community knowledge is not incorporated appropriately in technical risk assessments; so, we propose to apply Borromean Rings and Fuzzy Logic Systems for solving this issue. Based on the results of several field-trip observations, from a geotechnical perspective, is crucial to recognize that the primary destabilization mechanism of volcanoclastic deposits involves block failures rather than debris wasting. Once the destabilization happens, volcanoclastic materials travel longer distances as post-eruptive lahars and hyperconcentrated flows than syn-eruptive volcanic phenomena. On the other hand, there are specific interconnections among the probable source of a geological event and the community cosmovision of its territory. Therefore, effective technical risk assessment must integrate hazard analysis with ontologicity evaluation, incorporating in each one of them the community voices and knowledge. Fuzzy Logic Systems offer a unique framework for this integration, by translating human opinions into mathematical models through fuzzy rules. This study presents the application of Fuzzy Logic Systems, based on sketches from Borromean Rings, to assess simultaneously mass movements and volcanic risks in volcanic environments. It is done with special focus on embedding community insights and scientific knowledge together, rather than applying directly the technician's framework in the process of risk assessment of this geo-societal phenomenon.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Disruption to airport operations by volcanic ash fall

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Volcanic ash is a significant hazard to aviation, both because of the potential for physical impacts and for network disruption caused by airspace and airport closures. Until now, ash fall impacts on airport operations have received much less attention than airborne ash impacts on aviation. The time and resources taken to remove ash fall from runways and airport infrastructure can cause extended disruption to the aviation network, far beyond the presence of ash in the atmosphere. Here, using publicly available information and building on the work of Guffanti et al. (2008), we compiled a global dataset of 253 ash fall induced airport closure events between 1944 and 2023. We use this dataset to categorise impacts into five states: <1 day, 1-2 days, 3-7 days, >1 week, and permanent closure, and develop fragility curves for each state. The curves show that there is an ~80% probability of airport closure even for trace amounts of ash fall and that with a 1 mm ash fall, closures of more than one or two days are very likely (~90% and ~70%, respectively). Data points are concentrated between 1 and 100 mm thickness such that fragility curve uncertainties are greatest at the smaller and larger thicknesses. In addition to ash fall thickness, closure duration is affected by airport or national emergency management policies, resources available (personnel/equipment), and environmental conditions. This dataset and derived curves provide a starting point and global evidence base for better understanding the impact of volcanic ash fall on airport operations.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

How do we move closer to near real-time volcanic hazard and risk estimation?

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The impacts of future volcanic eruptions are expected to amplify due to global population growth, driving more people to settle on hazardous lands, and modern society's rising vulnerability to volcanic hazards. However, those future eruption impacts (e.g., material, non-material, human) are challenging to forecast robustly. One of the reasons is that, when forecasting impacts, we often consider a future volcanic eruption as an instantaneous event at a specific point in time, rather than considering the dynamic, coincident, and cascading impacts associated with a potentially multi-phase and multi-hazard volcanic eruption. To more accurately constrain forecasts of impact and loss resulting from eruptions, we ideally need to incorporate these dynamic aspects into our impact forecasts. One approach is to move closer to near real-time volcanic hazard and risk estimations, which use real-time data to rapidly and robustly forecast imminent impacts. In this project, we will extend our current machine-learning model based framework, which uses monitoring data (i.e., progressively added seismic, deformation, degassing data with time; before and during an eruption) to optimise the forecasting of volcanic eruption onsets. We will investigate how well monitoring data can forecast eruption duration and the changing characteristics of activity within a multi-phase eruption to inform dynamic and updateable forecasts of potential hazard. By combining this with developments on dynamic and interacting volcanic eruption impacts (i.e., studying the relationships between impacts from different/coinciding/cascading hazards and the forecasted eruption parameters), we aim to develop a dynamically updating framework for optimised impact estimation.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Using the value chain approach in Samoa to assess and prioritise multi-hazard early warning system vulnerabilities

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[3]*Samoa Meteorology, Geoscience and Ozone Services Division, Apia, Samoa* Samoa is a small island developing State in the central South Pacific, with mountainous volcanic topography and a population of around 205,000 living mostly near the coasts of two main islands. The country is exposed to many natural hazards, including tropical cyclones, volcanic eruptions, tsunamis, floods, earthquakes, landslides and forest fires. During the past six years, Samoa has made considerable efforts to upgrade its multi-hazard early warning system (MHEWS) governance, policy and procedures, and intends to continue this work with the support of partners and donors. To invest in improving this MHEWS requires an objective understanding of system vulnerabilities from an integrated, multi-disciplinary risk-based perspective that explicitly includes meteorological and geohazard events. Some past external assessments in Samoa and elsewhere have neglected to include geohazard components, perhaps because of a focus on climate-related issues. During early 2024, we adapted work from the World Meteorological Organization's HIWeather Value Chain project to produce an MHEWS warning chain assessment matrix, with hazards listed in priority order and the vulnerabilities of different capabilities and outputs along the chain colour-coded according to the level of concern. The results highlighted critical points of MHEWS failure in unexpected places along the warning chain, as well as many areas where investment, integration, and other system improvements are needed. This matrix was then used to inform a series of urgent, strategic and operational recommendations for MHEWS improvement, and including for volcanic hazards.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Mapped geologic features used to forecast long-term likelihood of future eruption locations: applications during an ongoing series of frequent, differing-impact eruptions on the Reykjanes Peninsula, Iceland

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Since 2020, magma intrusions and eruptions have occurred on the Reykjanes Peninsula. The current activity varies from eruptions constrained in remote valleys to eruptions affecting critical infrastructure, such as the town of Grindavík, power lines, water pipes, a power plant and a popular tourist attraction. For long-term hazard assessment, the Matlab code MatHaz was applied to calculate the spatial probability of future eruptions on the peninsula. The input data are mapped geologic features: past eruption sites, fractures, geothermal areas, and the plate boundary. Input data changes over time: for example, new eruption sites are appended to the previous ones. Lava flows from younger vents can erase surficial record of an older vent, therefore the input of short-lived vent locations must be coarsened to be consistent with the geologic record of older eruptions. Scientific choices such as how to update critical input data generate additional, ongoing sources of uncertainty. Discussing long-term hazard results during an on-going event is particularly sensitive, both in terms of conveying the uncertainty of the results as well as ensuring that assessments made for a long-term purpose are not misapplied. During events that cause societal upheaval, non-ambiguous answers about an ongoing crisis are often desired. It is important to reemphasize that unlikely events can happen. It is a challenge to optimize communication of the breadth of results made possible through this approach of quantifying likelihood based on mapped geologic features. Making decisions about when it may be beneficial/harmful to emphasize worst-case scenarios is an on-going conversation.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Assessing Tephra Mass Deposition on Roads for Effective Management of Volcanic Eruption Impacts: The Case of Mount Etna, Italy

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Explosive volcanic eruptions release large amounts of tephra, which can spread widely and accumulate on the ground, causing significant damage and disruption to public infrastructure, including transportation networks. The dispersal and deposition of tephra depend on various factors, such as the mass eruption rate (MER), tephra characteristics (e.g., size, shape, and density), plume height (H_{TP}), grain size distribution (GSD), and local wind conditions. This study focuses on quantifying the tephra mass deposited on the road network along the east-southeast flanks of Mount Etna, Italy, during the sequence of lava fountain events of 2021. We analyzed a series of 39 events detected by X-band weather radar, using the volcanic ash radar retrieval (VARR) technique that allows us to calculate key eruption source parameters (ESPs) such as MER, H_{TP}, and GSD. When radar data were unavailable we derived the ESPs using images from both the SEVIRI radiometer and from the visible/thermal infrared cameras operated by the INGV, Osservatorio Etneo (Catania). The ESPs were then used as inputs to run two different dispersion models, TEPHRA2 and FALL3D, which simulate the dispersion and fallout of volcanic tephra. The output of the model runs were processed to produce geo-referenced estimates of the tephra mass deposited across the entire road network of three nearby municipalities, enabling us to identify which roads were most heavily impacted by tephra accumulation. These data provides valuable insights for planning and managing the short-term tephra load hazard during future explosive events at Etna.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Assessing volcanic multi-hazard risk on the road network using the ADVISE methodology: the case of Vulcano Island, Italy

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Volcanic eruptions are among the most complex natural phenomena as they can produce multiple hazards, often causing spatio-temporal overlapping impacts. With increasing exposure in volcanic areas, comprehensive risk assessments are key to reduce the consequences of eruptions. Assessing the risk to road networks is crucial both to short-term and long-term risk management to facilitate access to key infrastructure and evacuation of inhabitants, as well as to improve land-use and development plans. This work attempts to combine multiple hazards (i.e., tephra fallout and volcanic ballistic projectiles) to estimate the potential risk on the road network of Vulcano Island (Italy) using the ADVISE methodology. In order to homogenise the hazards effects, a four-level hazard scale is proposed, taking into account not only physical but also functional impacts. The highest level of multi-hazard risk is associated with the road connecting the north (Porto) and the west (Lentia) of the island, as well as the first part of the road connecting to the south port (Gelso). These results are especially important given the lack of redundancy of the road network of Vulcano island and the key role that these two road segments play in case of evacuation.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

Vulnerability of agriculture to tephra fall: A systematic review of research approaches

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Agriculture in volcanic regions faces significant risks, as tephra emissions during explosive eruptions threaten livelihoods, food security and community resilience on local to regional scales. Tephra fall can impact crops, livestock, soils and farm infrastructure, triggering cascading effects throughout the agri-food system. This study presents a systematic, cross-disciplinary review of scientific literature on agricultural vulnerability to tephra using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. We developed a typology of research approaches to classify and compare methodologies, outcomes and target audiences, providing a structured perspective of the strengths and limitations of existing studies. The review highlights fragmentation across disciplines, with a predominant reliance on quantitative approaches, such as vulnerability functions, GIS-based analyses and probabilistic models, compared to mixed or qualitative methods. Most studies focus on physical impacts on agriculture, including crop yield losses and infrastructure damage. However, systemic vulnerabilities, such as cascading effects on value chains, labour disruptions and market access challenges, are rarely addressed and only partially explored. Similarly, community-level adaptative strategies and long-term resilience planning remain largely underexplored. This reveals a critical lack of integration between biophysical and socio-economic dimensions in analysing agricultural vulnerability to tephra hazards. Recent FAO and UNDRR reports emphasize the growing recognition of this integration as essential for understanding the complex, interrelated factors that shape the vulnerability and resilience of agroecosystems in a changing environment. We propose a research strategy aimed at strengthening our capacity to support the development of resilient agro-systems in volcanically active regions.

Theme: 6. Hazard, Risk and Impact

Session 6.7: Advances in volcanic hazard and risk assessments and the quantification of associated uncertainties

Allocated presentation: Poster

A new high-resolution hazard map for Villarrica volcano, Southern Chile: Methodology and Results

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Villarrica Volcano (2,847 m a.s.l.; 39°25' S, 71°56' W) is recognized as the volcanic system with the highest Holocene eruptive recurrence in Chile (one eruption every 4.85 years) and represents the highest risk in the country. In 2000, the Geological Survey of Chile (Sernageomin) published the first 1:75,000 scale hazard map for Villarrica, primarily to support emergency response during an eruption. Over the past two decades, advances in simulation tools, higher-resolution topography, and a significant post-pandemic population increase in the region have emphasized the need for more detailed hazard assessments to inform land-use planning. This study provides a detailed analysis of the northern sector of the Villarrica volcano by constructing an integrated volcanic hazard map at a scale of 1:25,000. The volcanic hazard assessment addresses lava flows, pyroclastic density flows, lahars, tephra accumulation, and ballistics, based on field data, literature review, and numerical simulations. Eruptive scenarios were defined to identify exposed areas from each process, which were then classified into four hazard levels: very high, high, moderate, and low, using a semi-quantitative integration matrix based on magnitude, recurrence, and potential impact. Approximately 50,172 people in the northern sector of the volcano are exposed to multiple levels of hazard. In addition, major economic activities such as tourism, agriculture, and forestry could be severely affected by an eruption. This product is the first detailed scale volcanic hazard map in Chile and provides a significant contribution to volcanic risk management in the region.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Talk

What is causing the El Chichón crater lake non-seasonal large-size variations?

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A few weeks after the major explosive eruption of El Chichón volcano in 1982, which caused the worst volcanic disaster in Mexico, a lake formed on the floor of the 1 km wide, 200 m deep crater carved by the intense explosions. Since then, discontinuous yet persistent monitoring of various geophysical and geochemical parameters revealed different interaction regimes between the lake and the underlying hydrothermal and magmatic systems. In particular, the correlations between the evolution of some hydrogeochemical parameters like pH, B, and Cl^- and the varying crater lake area revealed significant changes in the magmatic and hydrothermal influence on the lake water. Distinctly different changes in those regimes have been recognized in 1983 and 2002. Identifying the causes of the regime changes represents a critical problem for assessing volcanic hazards. Searching for possible origins of the hydrogeochemical and lake size variations, we inferred that the loss of permeability of the interface between the lake and the underlying systems caused the first regime change in 1983. Then, we analyzed several other possible causes for the second change, including the seismicity within 12 km around the volcano. We found that in the period 1990-2006, only one M 4.0 earthquake was recorded in that area on October 9, 2002. This event may have altered the degree of interaction between the lake water and the hydrothermal system, modifying the stress and displacement in two fractures crossing the volcanic edifice: Chichón-Catedral (NW-SE) and San Juan (E-W) faults.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Talk

Recent changes in hydrothermal dynamics at the Boiling Lake, Dominica: Implications for Instability, Gas Release, and Volcanic Hazards

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Since 1900, the Boiling Lake in Dominica has experienced at least ten instances of rapid draining and refilling, reflecting instability in its hydrothermal system. During these disturbances, harmful gases like carbon dioxide can be released suddenly and small steam explosions may occur, which pose hazards to visitors to the lake. After a Mw6.3 earthquake in 2004, ~40 km north of Dominica, the lake underwent a period of instability from December 2004 to April 2005. The lake's chemistry also shifted from an acidic to a more neutral composition, a change that has since not been reversed. These episodes of instability, observed more frequently in recent decades, suggest significant local changes in the volcano-hydrothermal system. Recent research indicates that water levels are maintained by volcanic gas bubbles rising through cracks in the lake's bedrock. When these vents are blocked—due to landslides or other disruptions—the water level falls as gas is no longer released. Improved monitoring utilizing thermal and satellite imagery provides an opportunity to reassess the processes driving these episodes. This research aims to enhance the hydrogeochemical model of the lake, offering better insights into the mechanisms of instability and helping to improve the understanding of volcanic hazards at the lake.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Talk

Monitoring the impacts of methane extraction on the stability of stratification in Lake Kivu

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Lake Kivu is a large East African rift lake renowned for the high amounts of gases (~60 km^3 of methane and ~300 km^3 of CO_2) dissolved in its deep waters. These gases represent an enormous risk, as their hypothetical eruption would far exceed the catastrophic events that occurred at the Cameroonian crater lakes Monoun and Nyos. However, the dissolved methane is also a valuable resource, which has been exploited at commercial scale since 2016 by Kivuwatt, and further expansion of the extraction is foreseen by the governments of Rwanda and the Democratic Republic of the Congo. While stable density stratification currently prevents gas release, the lake's vertical density structure may evolve, especially due to the water flows induced by the methane extraction activities. Our study aims to assess how methane extraction has modified the density stratification in the lake since 2016, and how these changes compare to the natural changes observed before 2016 as well as to previous model predictions. We analyzed 2524 Conductivity-Temperature-Depth (CTD) profiles collected between 2008 and 2022 by monitoring programs of the Rwanda Environment Management Authority (REMA) and KivuWatt. The results show that the reinjection of degassed water following methane extraction formed a new saline layer just above the main density gradient and that the combination of extraction and injection water flows led to a slow drawdown of that gradient. These changes qualitatively confirm the model predictions, although they seem to proceed faster than expected, highlighting the need for continued monitoring and evaluation.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Talk

Quantitative evaluation of temporal changes in subaqueous hydrothermal activity in active crater lakes during unrest: Time-series analyses of lake chemistry

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Regular sampling of lake water has been performed at many volcanoes to evaluate the state of volcanic activity. However, it is not clear whether the absolute concentrations or rate of changes in concentrations are more suitable for such evaluations. In this study, we show that temporal changes in concentrations of an element in lake water are described by a simple differential equation. The response time (63%) to change in the chemical concentration in lake water ranges between 20–1,000 day for the volcanoes in Japan, meaning it can take a long time to evaluate volcanic activity based on the absolute chemical concentration. In order to evaluate changes in volcanic activity in a shorter time period, we developed a simple numerical method to calculate temporal changes in the bulk hydrothermal fluid injected from fumaroles and hot springs at the lake bottom. We applied our method to Yugama crater lake at Kusatsu–Shirane volcano, Japan, and quantitatively evaluated temporal changes in the hydrothermal input from 1964 to 2020. As a result, we detected changes in concentrations of several elements in the bulk hydrothermal input that were associated with unrest including the phreatic eruption and earthquake swarms. The future concentration in the lake water can be predicted from the time-series of lake concentrations. Comparing the predicted concentration curve with the concentration obtained from lake water samples, it is possible to quickly evaluate whether the concentration of the bulk hydrothermal input has increased, decreased, or remained constant.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Talk

Enhancing Satellite-Based Volcanic Lakes Monitoring with the VRP$_{TIR}$: A Novel Approach to Quantifying Radiative Power using Thermal InfraRed (TIR) Data

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Volcanic crater lakes are present at over 15% of Holocene volcanoes and account for ~15% of volcanic eruption-related fatalities, despite hosting only ~3.5% of recorded eruptions. Monitoring physical variations in these lakes is crucial for the early detection of volcanic resurgence. However, their hazardous, gas-rich, and corrosive environments make continuous ground-based monitoring impractical, leading to significant gaps, or complete lack, of data. Thermal InfraRed (TIR) satellite data offer a risk-free alternative to monitor these systems. TIR-based radiative power measurements can reveal subtle variations in thermal outputs that anticipate rapidly escalating volcanic phenomena. Yet, traditional methods for estimating radiative power either target high-temperature features or underestimate outputs from low-to- moderate-temperature systems by up to ~90%. We here present the results from applying the TIRVolcH algorithm to globally selected crater lakes and introduce the TIR-based Volcanic Radiative Power (VRP$_{TIR}$). This novel method accurately quantifies radiative power for systems dominated by temperatures ≤600 K, using single-band TIR radiance (10.5–12 μm), with an uncertainty of ±35%. VRP$_{TIR}$ enables the detection of subtle variations in volcanic thermal activity, providing critical insights into baseline behaviour and transitions to unrest. Its global applicability and integration with targeted measurements and modelling make it a vital tool for hazard mitigation and advancing the understanding of volcanic lake processes. By improving the accuracy of radiative power retrievals, VRP$_{TIR}$ supports the development of long-term global inventories of volcanic energy loss, offering a key contribution to multidisciplinary approaches for volcanic lake monitoring.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Talk

Modeling and observing the dynamics of Lake Albano: present state and potential hazards under global warming future scenarios

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Lake Albano is a monomictic volcanic crater lake in Central Italy with CO_2-rich waters. Depending on the period of the year, the lake is characterized by strong stratification or rather overturning events. In the warm season, the heating of the surface water results in a highly stratified vertical density profile, while in the cold season, the surface water cooling leads to a potential vertical instability of the water column. In this case, a partial/deep overturning of the lake water column may occur with the release in the atmosphere of the CO_2 which was accumulated likely due to the fracturing of the bedrock in consequence of seismic activity. Such a process has been periodically observed in Lake Albano in the past and could pose a potential hazard to the surrounding environment and population. A 3D numerical model was implemented to investigate the lake dynamics, with the support of instrumental data collected to calibrate and validate the model. Two numerical experiments, using different atmospheric forcing datasets, were conducted to identify past overturning events. Additionally, a future scenario simulation covering the period 2025–2044 was performed to investigate how lacustrine dynamics might respond to global warming conditions. These conditions could severely inhibit the preconditioning phases necessary for lake overturning, which in turn could reduce the frequency of overturning events, leading to the accumulation of larger amounts of CO_2 in the lake. This buildup could then result in hazardous CO_2 releases.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

Tracking mineral precipitation, dissolution, and alteration below volcanic lakes using vertical temperature profiles

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Heat, groundwater, and CO_2 flow beneath volcanic lakes is controlled by the evolution of structures and water-rock interactions. We couple new campaign lake floor heat flow measurements and long-term water column temperature monitoring to characterize variations in heat flow controlled by dissolution, precipitation, and alteration of minerals in the sediments below volcanic lakes. Our study is focused on Mono Lake in eastern California which hosts 350-700-year-old volcanic features. We collected 62 shallow (<1.5 m penetration) temperature profile measurements. Heat flow, vertical fluid velocity, and bulk thermal diffusivity are estimated by solving the advection-diffusion equation using long-term water column temperature monitoring data to constrain boundary conditions and reducing misfit between modeled and observed temperatures. On the southern shores of Mono Lake, faults connected to deeper magmatic systems transport groundwater and CO_2 into the lake. Within these fault zones, we observe two different types of sublacustrine springs. One set has near surface fluid temperatures of ~30 °C and contains magmatic CO_2 that lowers the pH (6-7) relative to the lake water pH (10-11). Up flow at these springs dissolves carbonate minerals resulting in thermal diffusivity of ~2.5×10^{-7} m^2/s. Cool (~20 °C) groundwater emerging from below the lake not containing CO_2 reacts with the lake water to precipitate carbonates in the shallow sediments, elevating thermal diffusivity to ~7×10^{-7} m^2/s. These results show promise for using temperature monitoring to track fluid flow, and mineral precipitation, dissolution, and alteration associated with active hydrothermal and shallow magmatic processes below volcanic lakes.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

Sulfur scrubbing and remobilization at Poás: Implications for gas monitoring at volcanic lakes

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Gas monitoring using in-situ MultiGAS stations at Poás volcano has shown that key gas ratios (SO_2/CO_2 and H_2S/SO_2) change with eruptive activity and geophysical signals. However, interpreting these correlations requires understanding of complex sulfur dynamics in hydrothermal-magmatic systems. The latest cycle of lake growth and disappearance between 2019 and 2024 at Poás provides an opportunity to investigate sulfur scrubbing. During this period we estimate that ~118 ktons S was degassed to the atmosphere as SO_2, compared to ~68 ktons of elemental S deposited by the lake, and ~65 ktons emitted by flank springs as dissolved sulfate. The lake itself is an ephemeral S sink containing <15 ktons S as dissolved bisulfate. Therefore, at least half of the SO_2 released from the magma is scrubbed by the hydrothermal system. Elemental S is likely generated by both H_2S oxidation and SO_2 disproportionation, as evidenced by decreasing H_2S/SO_2 and decreasing SO_2/CO_2 during lake growth. Eruptive episodes at Poás are associated with high SO_2/CO_2 , likely due to increased magmatic SO_2 input. However, CO_2- SO_2-H_2S systematics suggest that revolatilization of elemental S and dissolved bisulfate could be significant processes during eruptive degassing. Sulfur isotopes should be a powerful tool for distinguishing between magmatic gas and secondary gases produced by scrubbing/remobilization processes. To this end we have collected time-series plume and fumarole samples to determine the sulfur isotope compositions of both SO_2 and H_2S, as well as samples of secondary products, which we will present to further investigate dynamic changes in sulfur processing at Poás.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

Early warning system for detecting unexpected changes in Lake Kivu stratification

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Lake Kivu, a meromictic lake rich in carbon dioxide (CO_2) and methane (CH_4), is situated in an active volcanic region on the border between Rwanda and the Democratic Republic of the Congo. While it is socio-economically important for millions of people, the lake also poses significant risks. Subaquatic inflows originating from geological systems associated with two active volcanoes, Nyamuragira and Nyiragongo, maintain its permanent stratification and enable the accumulation of high concentrations of dissolved gases in its deep waters. This makes Lake Kivu vulnerable to catastrophic gas eruptions, posing a threat to over 2 million people living around its shores. Although, studies suggested that Lake Kivu is currently close to a steady state, active monitoring remains crucial to avoid potential disasters similar to the limnic eruptions in the two Cameroonian Lakes Nyos and Monoun. This work highlights the extent to which Lake Kivu's stratification changes can be attributed to various drivers, including volcanic influences. It also introduces a framework for an Early Warning System (EWS) to detect and alert unexpected stratification changes, particularly those driven by volcanic activity. The proposed EWS will enhance the existing lake model by integrating it with a lake monitoring observational database. This linkage will enable continuous comparison between observed data and model projections, allowing the system to flag unusual deviations. By providing insights into interactions between volcanic activity and lake dynamics, the system aims to strengthen hazard management and mitigate risks of limnic eruptions, ensuring community safety and preserving Lake Kivu's ecosystem.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

New insights into the volcanic unrest at Campi Flegrei (southern Italy) based on an integrated geochemical and microbiological investigation at Astroni lakes.

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Astroni is a 2×1 km wide crater in the Campi Flegrei caldera (southern Italy) hosting three small lakes, namely Lago Grande (LG), Cofaniello Grande (CG), and Cofaniello Piccolo (CP), presenting a varied ecosystem rich in reeds, bulrushes and willows. In this study, possible relationships between the lakes and the hydrothermal fluid circulation system were investigated based on geochemical data of the lakes and microbiological analyses of lake waters and sediments. Lake chemistry, showing a Na^+-HCO_3^- facies and relatively high TDS values (up to 1,820 mg/L), was consistent to that typically found in discharges located at the periphery of upflow zones of active hydrothermal-volcanic systems. LG was characterized by an anoxic hypolimnion with relevant concentrations of biogenic CH_4 and a mixture of biogenic and hydrothermal CO_2. The dependence of the chemistry of the Astroni lakes on inputs from the Campi Flegrei hydrothermal system may explain the anomalous increase of the LG water level recorded in the last years, which was not consistent with the temporal pattern of rainfall in that area and never observed before. The increasing hydraulic pressure related to the enhanced hydrothermal steam condensation recorded in the last decades can indeed have caused the observed change in the LG water volume. The increase of the LG water level, besides acting as an indicator for the volcanic crisis, may have a strong environmental impact, since it affects the terrestrial and aquatic

compartments of the Astroni crater, with direct consequences on the unique ecosystem functioning of the lakes.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

Geochemical characterization of piping-sinkhole lakes as a potential monitoring tool in seismogenic areas

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Natural sinkholes are depressions in the ground that are commonly associated with karst and/or intense fracturing and faulting. Seismic events favor the uprising of endogenous fluids that may cause rock dissolution and produce piping-sinkholes. The latter may develop in areas of CO_2-rich gas emissions and, when an aquifer is present, create small lakes potentially rich in dissolved CO_2(CH_4) at depth, with characteristics similar to bio-activity volcanic lakes. The results of geochemical surveys carried out in winter and summer at Paterno (LP) and Telese (LT) lakes are here reported. These two lakes are piping-sinkholes located in seismically active areas of central-southern Italy where CO_2-rich springs occur. They have maximum depths of 54 and 17 m, respectively, a Ca(Mg)-HCO_3 composition and are monomictic, with the establishment of thermal and chemical stratification in summer. During the latter, the CO_2 concentrations in the hypolimnion were up to 0.53 and 0.13 mmol/L in LP and LT, respectively, while the $\delta^{13}C$-CO_2 values ranged from -8.6 to -7.2 ‰ vs. V-PDB, indicating a contribution of crustal fluids. According to these data, inputs into the lakes of deep fluids, related to seismic activity, may be revealed by changes of the chemical and isotopic features of the lake waters. Therefore, these lakes could be considered promising sites for monitoring seismic activity.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

Native sulfur spherules from volcanic water lake and fumaroles (La Soufrière Volcano, Guadeloupe)

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The level of unrest and state of activity of volcanoes is typically assessed by time series changes of monitoring geophysical and geochemical data. In the case of La Soufrière de Guadeloupe, this includes tracking the composition and temperature of the numerous fumaroles and water from the Tarissan crater lake as the hydrothermal activity is very important at this volcano. Here we report the results of studying the solid particles found in the Tarissan lake and fumaroles as a complementary way to identify changes in the temperature and fluid compositions. We found sulfur spherules of a variety of sizes (typically < 1 mm) that are aggregated and welded in a range of morphologies. Their occurrence indicate temperatures > 113°C in order to have liquid sulfur which agrees with some of the temperatures of the fumaroles but it is higher than that of the water lake (< 110°C). We hypothesize that the spherules collected in fumaroles result from the melting of sulfur crystals previously deposited at lower temperature. This explanation is supported by the recent increase of fumaroles temperature from 95-110°C to 180-210°C. Conversely the origin of Tarissan lake spherules is uncertain. Sulfur spherules have also been reported in other volcanic lakes worldwide (Poas, Costa Rica; Hakone, Japan; among others) and time series changes in presence or absence, their textures, and sizes may be also useful for assessing changes of the hydrothermal and magmatic systems below La Soufrière and thus eventually contribute to identify upcoming eruptions/explosions at this volcano.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

Lahar triggering mechanisms at Lake Albano (Rome, Italy): evidence from archaeology, volcanology and numerical modeling

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There is geological evidence that the hydrological network on the northwest flank of Colli Albani volcano, 10 km southeast of Rome, has been buried by lahar deposits since 21 ka. The indisputable candidate of water source for lahar generation is Lake Albano: however, it remains unknown how water was expelled during numerous lahars events. A drainage tunnel, presumably constructed by the Romans after a lake flooding in 398 BC, should have mitigated lahar hazards by keeping the lake level 70 m below the lowest crater rim. Nevertheless, recent archaeological discoveries revealed that the site of Marcandreola, 4 km northwest of Lake Albano, a highly frequented centre since Archaic Age (753-510 BC) was covered by a lahar, dated to have occurred 270-280 BC, i.e. *after* the construction of the tunnel. Given these premises, we investigate the causes of this lahar. The lake bathymetry and crater topography show two main landslide scars, representing the sources of worst-case-scenarios, feeding subsequent numerical modeling. Based on these models we ruled out that a landslide generated tsunami alone could have caused lake throw out. Posteriorly, several scenarios of additional energy sources are explored: (1) a limnic gas burst, (2) a higher lake level (putting in discussion the age and state of the drainage tunnel), or (3) a combination of both. The recognition of numerous landslides in and around the Lake Albano basin, and the occasional co-seismic gas input causing gas build-up in the lake, highlights the need to revise and strengthen monitoring and mitigation strategies.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

CO2 diffuse degassing in volcanic lakes in Ecuador

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Active volcanic lakes pose the hazard of limnic eruptions as water can retain volcanic gases and suddenly release them during quiescent periods. Cuicocha and Quilotoa, Ecuador, are volcanic lakes whose last eruptions occurred 3000- and 800-years BP, respectively. Both are surrounded by inhabited areas and are important touristic sites in the country. At Quilotoa, a limnic eruption killing all the cattle grazing inside the crater is described in the historical chronicles. This event occurred in 1797 and is related to the Riobamba earthquake (M_{ic} 7.6, about 100 km to the south). In order to identify seasonal patterns and to evaluate the potential hazard of occurrence of limnic eruptions, we perform periodic diffused CO_2 surveys using the accumulation chamber method at both lakes. The diffused CO_2 emissions at Cuicocha have been measured for more than a decade, revealing strong spatial and seasonal control in the degassing process. CO_2 for Cuicocha is of 34 g/m^2/d, with some values reaching up to 63 g/m^2/d. For Quilotoa, CO_2 emissions have been measured five times between 2014 and 2018, showing values ranging from 46 to 180 g/m2/d. Recent measurements, during 2024, reveal fluxes of up to 110 g/m^2/d which are significantly higher than the average reported for Cuicocha. Interestingly, these values are also much higher than those measured at lake Nyos (~8 g/m^2/d), where a catastrophic limnic eruption caused about 1500 casualties in1986. A better understanding of the CO_2-degassing dynamics at both lakes, will enhance the ability to forecast these hazardous phenomena in the future.

Theme: 6. Hazard, Risk and Impact

Session 6.8: Multidisciplinary monitoring and modelling of volcanic lakes as a tool for hazard forecast and mitigation

Allocated presentation: Poster

CO2 and CH4 fluxes from Congro and Santiago volcanic lakes (São Miguel, Azores)

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Congro Lake is located in the SW quadrant of the Congro Fissural Volcanic System, the easternmost of the two active fissural systems of São Miguel Island (São Miguel, Azores). Lagoa de Santiago is located on the SE sector of the Sete Cidades central volcano caldera. Both lakes are associated to maar craters, the former corresponding to a crater of broadly circular shape and a diameter of approximately 500 m, and the latter occupying a crater measuring 1.1 km by 0.8 km across. The surface area and maximum depth are equal to 0.04 km^2 and 22 m, for Congro, and 0.25 km^2 and 33 m, for Santiago, being the estimated water residence times respectively about 7.3 and 24.5 years. To measure the CO_2 and CH_4 diffusive fluxes two surveys were conducted in both lakes using accumulation chambers. For CO_2, 65 and 100 measurements were made in Congro, respectively for surveys 1 and 2, and 173 and 140 measurements were carried out in Santiago. For CH_4, several transepts were made, each with 6 static floating chambers, totalizing 3 and 6 transepts for Congro and 2 and 6 for Santiago, respectively for the 1st and 2nd surveys. Using the sGs method, CO_2 flux at Congro range between 0.11 to 0.18 t/d (2.75 $t.km^{-2}.d^{-1}$ - 4.74 $t.km^{-2}.d^{-1}$) and at Santiago between 0.22 to 1.88 t/d (0.95 $t.km^{-2}.d^{-1}$ – 7.43 $t.km^{-2}.d^{-1}$). Instead, extrapolating the measured CH_4 flux, values are much smaller, being equal to 15.1×10^{-6} $kg.m^{-2}.d^{-1}$ and 7.4×10^{-6} $kg.m^{-2}.d^{-1}$, respectively for Congro and Santiago lakes.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Talk

Volcanic Geo Heritage in India: Engaging with the community for transferring geosciences to society through geo education and nature conservation.

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Indian subcontinent exhibits imprints of varied geological and volcanic processes through ages and is a storehouse of interesting geological features which are recognized as geo heritage sites. Geological Survey of India has already enlisted some of those locales as National Geological Monuments. However volcanic geo heritage site remains the attraction of geo tourism and geo cultural heritage for the communities around the globe. This presentation focuses on various Volcanic geo heritage sites in India focusing on scientific and social importance. The Deccan Traps continental flood basalt province, more than 65 million years in age and covering more than 500,000 km2 areas of western and central India, contains some 1200 rock-cut caves which are formed due to volcanic process. Ajantha and Ellora caves in the Deccan Basalt Trap are fines example of geo heritage in Asia. The Elephanta, marine caves in Arabian Sea near Mumbai coast in India is example of Marine Volcanic geo heritage site. This presentation focuses on geological understanding of The Ajanta and Ellora Caves and its importance in local economic development, world-renowned historical, cultural, religious and artistic monuments and ancient rock-engineering marvels in India, are also monuments for flood basalt geology and volcanology and ancient volcanic geo-heritage. The presentation also deals with lesson learned in past in Engaging with the community for transferring geosciences to society through geo education and nature conservation. The presentation aims in providing a scientific platform to share recent developments in this emerging field of volcanic geo heritage sites in India and Asia at large.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Talk

Integrating indigenous myths with new scientific knowledge on late Holocene eruptions of Isarog volcano, Philippines

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Prior to its classification as a potentially active volcano and its subsequent reclassification as active based on new ^{14}C ages in 2013, Isarog volcano in Camarines Sur, Philippines was widely considered extinct from the 19th to mid-20th centuries due to the absence of recorded eruptions. Indigenous communities in the Partido District, however, recount myths that suggest otherwise. The ancient Bicol epic, Ibalón, mentioned an eruption of Isarog and two other volcanoes, accompanied by strong earthquakes. Local legends narrate stories of giant creatures residing in Isarog's crater whose conflicts led to eruptions. Much of the older population also speak of "eruptions of water" rather than magma, possibly indicating ancient crater breaches or lahars. Recent field investigations and ^{14}C dating of organic material from volcanic deposits revealed that Isarog's most recent eruption occurred sometime during the 12th century. The presence of a potsherd in a paleosol underlying the eruption's deposits suggests human habitation during this period and that people may have witnessed the event, and accounts of other eruptions of Isarog may also be preserved in local myths. Evidence of dome collapses and Plinian eruptions is supported by the presence of block-and-ash flow and tephra-fall deposits. Large boulders inferred to be from lahar deposits are scattered in rice fields 10–15 km downstream from the volcano's crater, providing evidence supporting the myths of catastrophic eruptions of water. Our study emphasizes the value of integrating indigenous knowledge with scientific investigation to uncover overlooked volcanic activity and better understand lesser-known volcanoes and their hazards.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Talk

Success in managing volcanic risk, a real-life example

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For communities living in volcanic areas, it is a huge challenge to deal with a volcanic reactivation and to manage the uncertainty of a possible eruption, even more so, when drastic actions are required, such as evacuation. In these complex situations, knowledge of the environment, perception of the volcanic phenomenon and the political, religious and personal context play an important role in how the authorities and the community deal with the emergency. This presentation shows the experience during the reactivation and volcanic eruptions in the area of 'Tierradentro' in the departments of Cauca and Huila in Colombia, where the NASA indigenous community faced the reactivation and eruptions of the Nevado del Huila volcano. Also, how the indigenous, local and national authorities interacted resulting in a response that allowed them, to manage the situations arising not only in moments of uncertainty about the occurrence of the eruption but also about its size and the needs of a region that could be strongly affected. Finally, three main Vulcanian-type eruptions occurred in February and April 2007 and November 2008, which generated columns of ash several thousand meters above the volcano, with the dispersion of ash mainly towards the West, the formation of a lava dome and small pyroclastic density current, in the eruption of November 2008, and the phenomenon with the greatest destructive power was the formation of lahars with large volumes along the rivers that drain the volcano and that reached distances where a good part of the community lives.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Talk

Geoheritage and digital advocacy: Using online tools to encourage geoconservation

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Geosites of volcanic eruptions that suddenly interrupted ancient settlements such as Herculaneum, Pompeii, and Akrotiri represent exceptional geoheritage interests. However, volcanic eruptions before human settlement are also of vital cultural importance. The stratigraphic succession exposed in Puertito de Adeje, South Tenerife, contains some of the best-preserved outcrops of the Adeje and Fañabé ignimbrites from eruptions >1.5Ma. Units of the Adeje ignimbrite show evidence of partial welding, indicative of high-temperature eruption, which is rare in Tenerife and of international scientific interest. GeoTenerife's open access VolcanoStories 'Sustainable Tourism' project aims to give scientific rigour to local concerns regarding a proposed tourism development on the site. Through collaboration with local and international students and experts, we reported on El Puertito's ignimbrites to advocate for their preservation in line with local sentiment. Producing various resources - a geological report, an interactive geological map, and landscape photography - highlighting the geoheritage of El Puertito. As a direct result, IGME listed El Puertito as a 'High Scientific Value' with a 'High Protection Priority' on the Spanish Inventory of Sites of Geological Interest. Over 2,000 people have signed up to adopt the site and report on threats to the ignimbrites and fall deposits in El Puertito, highlighting their engagement. The previous national record stood at under 200 sponsors. Accessible research paired with digital tools for advocacy, such as IGME's citizen science "Sponsor a Rock" programme, enables the public to advocate for elements of the abiotic environment, cultivating a geoconservation ethic in the public consciousness.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Talk

Co-creation with Indigenous communities during natural hazards research, education, and engagement

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Indigenous peoples are widely affected by natural hazards and their history and knowledge can directly inform on past events and mitigation strategies. One way to share such information is through the co-creation and co-production of materials and knowledge. Furthermore, the co-production of Indigenous Knowledge Systems with Western science is increasingly recognized as an important component of education and research. When done correctly, it draws on the strengths of the respective knowledge systems, ensures Indigenous data sovereignty, empowers communities, supports reconciliation, and fosters mutual respect. Furthermore, in the context of natural hazards and volcanology, we illustrate how co-designing and co-teaching courses can effectively enhance knowledge systems. We show that students value the weaving of Indigenous Knowledge with science, both within (Westernised) academic settings and during place-based experiential learning. This blending of Knowledge systems and pedagogical approaches can deepen connections to Indigenous ways of knowing as co-production studies are re-connections to Indigenous history and identity. We conclude by addressing some of the challenges faced and provide actionable solutions.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Talk

How to use volcanic geoheritage to contribute to urban sustainability: the Geocity project, Mexico City

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Cities often contain volcanic geoheritage that is important for urban sustainability and social well-being created through scientific research, geoeducation, recreation, esthetics, and nature conservation. Mexico City was founded in a beautiful setting: a shallow lake basin surrounded by snow-capped volcanoes. However, uncontrolled hyperurbanization has caused the loss of most natural spaces, to such an extent that city residents are poorly aware of both the risks and benefits associated with their volcanic environment. Young monogenetic volcanoes in the southern part of the city provide the last remnants of the original landscape and preserve part of the native flora and fauna of the basin. However, the population and the authorities ignore their value so that they do not get involved in their protection and upkeep, and this threatens their survival. I will present here the first results of the *Geocity Project* (CONAHCYT CBF-1049) that aims to form a network of geosites in the city, through providing academic support to existing efforts of conservation led by citizens or local authorities, hence building bridges within the local community. We apply methods from geology, biology and geography to determine the scientific value of these sites and identify the elements that threaten them. We also integrate perspectives from social sciences and humanities (archaeology, politics, economy, anthropology and geo-

esthetics) to understand the interactions between urban communities and their environment in the past and the present. Finally, we co-create solutions for the restoration and long-term conservation of these sites by sharing knowledge across the academia and civils.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Knowledge co-creation: Lived experiences shared in the local languages for an experiential knowledge-based volcano risk communication

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Through the years, the importance of language in effective communication for volcano disaster risk reduction has been recognized. In the Philippines, there are many challenges and opportunities brought about by language diversity in volcanic areas. Each volcano with distinct geology and eruption style, is also home to diverse people and communities, each with its own unique culture. The DOST-PHIVOLCS, through the DANAS Project (Earthquake, Tsunami, and Volcano Disaster Narratives for an Experiential Knowledge-based Science Communication) embarked on a systematic documentation of volcano disaster experiences in the local languages focusing on several active volcanoes- Pinatubo (Kapampangan, Tagalog), Taal (Tagalog), Mayon and Bulusan (two Bicolano variants), Kanlaon (Hiligaynon and Cebuano), and Hibok-hibok (Cebuano). Through the project, local knowledge and perceptions of volcano hazards and risks as expressed in the local languages were captured during video-documented interviews. These were transcribed and analyzed to be able to select descriptions of volcano phenomena as lived experiences. Selected local-language descriptions were then used together with the technical descriptions that volcanologists normally use. One of the outputs of the DANAS is the co-creation and development of inclusive, culturally sensitive, context-driven volcano information materials in the form of volcano-specific sourcebooks. By integrating local knowledge into risk communication strategies, the end goal is to help communities better understand and prepare for disasters through meaningful tools in the form of familiar materials in the daily-used languages.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Co-creation for enhanced geohazards awareness and communication, through geosites knowledge

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Geodiversity involves dynamic processes and geological hazards. But it also offers a range of geosystem services, including the cultural and educational benefits of geosites. Since inhabitants and tourists interact directly with geodiversity dynamics and geosystem services, it is crucial to effectively communicate geoscience knowledge and information on geological risk management. Therefore it is important to narrow the gap between science and society by promoting community participation in research on geosites, increasing understanding of their scientific value, geohazards and geosite management. To achieve this, we studied the small volcanic island of Stromboli (Italy), taking into account the various geohazards associated with it, including volcanic eruptions, landslides and tsunamis, as well as its rich geodiversity. A three-step methodological framework is developed for the effective communication of geoscience knowledge and geohazards through geosite education. We started with the co-creation by working on outreach activities and participating in local programs related to geosites. In this way, we could gather local information, learn about their false beliefs/knowledge and understand missing information. The second part is scientific research. This includes the evaluation of the geosites using the Geosite Inventory Form, which guarantees comprehensive documentation and informed decision-making for the management and conservation of geosites. The DPSIR (Drivers, Pressures, States, Impacts and Responses) framework is also being used to develop better geosite conservation and management. The final part is the communication of the obtained results through local community and awareness-raising activities. This helps to dispel panic caused by miscommunication or partial knowledge, particularly in the context of geohazards.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Matatuhi: Forecasting and environmental tohu, examples from Aotearoa-NZ

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Our world is changing faster and in ever more diverse ways – global records are being broken from droughts to floods. In Aotearoa we have seen cataclysmic flooding, catastrophic volcanic eruptions, and the Canterbury earthquakes. An essential task in managing and adapting to our future is being able to forecast it. Science is trying to keep up, but current forecasting models require large amounts of information, and tend to focus only on one small part of a system. Forecasts lack both sufficient data and knowledge to build reliable models. We, as scientists, are stuck. We believe that the way out is by taking a holistic methodology. Such an approach is intrinsic to Mātauranga Māori (*traditional knowledge*) which, moreover, provides for an alternative lens on what can be considered data, beyond instrumental readings. We know that adding more voices with alternate understandings leads to better, more transparent forecasts with accurate descriptions of uncertainty. Here, we present region-specific examples of tohu (*indicators*) from the iwi that whakapapa to these areas, including around Ruapehu, an active composite volcano on the Te Ika-a-Māui North Island, Aotearoa. This research will build robust forecasts of our environmental future, and shift the conversation in Aotearoa away from "How can Mātauranga Māori be fitted into science?" and towards "What can science do to support Mātauranga Māori?" We invite discussion around similar successful (or otherwise) approaches from the global volcanological community.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Upper Miocene Mtkvari Ignimbrite Geoheritage, Lesser Caucasus, Georgia: A historical ritual, defensive and residential area

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Since the Middle Miocene, Late Cenozoic subaerial volcanic activity in Eastern Anatolia and the western Lesser Caucasus began and continued until the Holocene. In Georgia, this magmatic activity formed the Samtskhe-Javakheti volcanic plateau (~4,500 km^2), which is traversed by the deep canyon of the Mtkvari River in its central part. This canyon exposes the lowermost Upper Miocene 800-1200 m thick volcanogenic formation (Goderdzi Formation), predominantly of andesitic composition (Skhirtladze, 1958). In the lower part of the Goderdzi formation, the 80-120 m thick ignitable (Kura/Mtkvari Ignimbrites) is exposed. It originates from the Upper Miocene Keltepe-Gumbati resurgent caldera and is continuously traced along the left banks of the Kura River for ~35 km (Makadze et al., 2024). Isotopic studies of this flow show that it contains a large mantle-derived component (εNd from +3.1; 87Sr/86Sr = 0.704316), and by the U-Pb method of zircons, it is dated to 7.5 ± 0.2 Ma. This flow crosses a regional fault followed by the Mtkvari River, along which the eastern block is submerged ~126 m below the western block (Okrostsvaridze et al., 2020). In addition to its scale, excellent exposures, and fascinating geological structure, the Mtkvari Ignimbrite is notable for containing numerous historical rock-cut buildings with ritual, defensive, and residential functions. The synthesis of geoheritage and cultural heritage is particularly remarkable in this region. Notable among these are the monumental Vardzia fortress-city, dating back to the early medieval period, with more than 600 carved rooms, and the Vahani/Vani monastery complex, which contains approximately 200 carved rooms.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

The volcanic geoheritage of the Kurile-Kamchatka Arc

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The Kurile-Kamchatka Island Arc (KKIA) is an integral component of the Pacific Ring of Fire, characterized by a complex evolutionary history. This complexity has led to the formation of diverse volcanic structures of various ages and types throughout the Quaternary period. This volcanic landscape, along with subsequent post-volcanic activity, attracts numerous tourists and expert visitors. Nonetheless, significant anthropogenic pressures have adversely affected these volcanic forms, leading to the degradation of primary volcanic structures. Among the 13 nature parks and reserves within the KKIA, only 4 lack active volcanoes or post-volcanic activity. In the 7 nature parks and reserves on Kamchatka, such as Klyuchevskoy, Vilyuchinsky, Kronotsky, and Nalychevo, and two reserves on the Kuriles (Kurilsky, Ostrovnoy), total of 35 volcanoes are situated within protected areas. Notably, Kamchatka alone hosts over 7,000 volcanic structures that have formed during the Quaternary time, in addition to 36 subaerial and 116 submarine volcanoes on the Kuriles. Preserving the volcanic geoheritage of Kamchatka and the Kurile Islands is essential for ensuring these unique natural sites remain available for future generations and specialists. The current conservation policies have proven inadequate in safeguarding volcanic heritage or effectively utilizing it for community-level geohazard resilience development. Successful volcanic geoconservation in this highly volcanically and seismically active region requires co-development, community involvement, and broader inclusion of geohazard experts in conservation efforts.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Volcanic Risk Perception from Mounts Cameroon and Nyiragongo Eruptions, Central Africa

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Approximately 2,000,000 people are exposed to volcanic risks in communities situated at the flanks of Mounts Cameroon (MC) and Nyiragongo (MN) volcanoes. This study sought to investigate risk perception from four previous eruptions of MC (1959, 1982, 1999, and 2000) and two previous eruptions of MN (1977 and 2002). The study was initiated with co-design workshops held with major stakeholders in the cities of Buea and Goma at the flanks of MC and MN, respectively in 2017. A non-random questionnaire survey was later conducted within 14 and 15 communities in Buea. Three age groups (18 - 30, 31 - 45 and >45 years) were considered. At MC and MN, ≥45% of the sampled participants (with a higher female population) perceived that the sampled eruptions posed a very high risk to the population. In terms of the effects, the age group of 18 - 30 was the least knowledgeable. In terms of direct effect on persons, over 90% of participants at MC and MN attested that they were overcome by fear/panic. On measures to cope with any likely eruption, the following order was established at the flanks of both volcanoes: sensitization of population, use of religious (prayers) and of traditional/indigenous strategies. In terms of future coping strategies, while the males at MC maintained sensitization as the favourite option, 62% of the males at MN opted for traditional/indigenous strategies. The female population at both MC and MN showed a higher preference for religious strategies like prayers.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Illustrated works present potential and challenge in holistic communication of volcanic and cultural heritage to public

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Volcanic forms feature in both the earliest human drawings and modern art, indicating our enduring desire to record them visually. People living in volcanic regions as diverse as Guatemala to Indonesia have multiple knowledges (spiritual, economic, cultural) of their landscape. With the relatively recent development of physical volcanology, newer scientific knowledge of volcanoes has been generated. Volcanic hazard assessment and communication is important, especially to nearby populations who may be at risk. However, scientific knowledge of volcanoes is often disseminated separate from (and may conflict with) other, older knowledges held by people living nearby. Initiatives that integrate different knowledges of volcanoes aim to celebrate their cultural significance while educating on the risks they pose. Several inspiring recent projects fuse the visual arts with physical volcanology to simultaneously explore multiple knowledges of volcanoes in public spaces located in volcanic regions. These projects provide valuable occasions for knowledge exchange and appreciation of both cultural and geo-heritage. Referencing both these projects and examples from my own practice, I explore how the visual arts (particularly illustration) provide opportunities to unite cultural heritage and volcanic knowledge in forms that can be shared with the public, including at-risk populations. Meanwhile, questions of collaboration, stakeholder roles, and dissemination must be addressed to focus project purpose. This work is an open invitation to other volcano scientists with experience or interest in integrating scientific knowledge of volcanoes with cultural understanding for holistic communication of volcanic geoheritage.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Exploring volcanic hazard perceptions in Andean communities around Quilotoa and Cuicocha volcanoes (Ecuador)

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In order to understand the link of the Andean Kichwa communities and their volcanic environment, we focused on two Andean volcanoes (Quilotoa and Cuicocha) sharing a similar volcanological, but different anthropological context. Indeed, these volcanoes are both crater lakes formed by large (VEI 5-6) explosive eruptions at 800 BP for Quilotoa and 3000 BP for Cuicocha. The territory around these volcanoes is occupied by Andean peasant communities, with medium size cities nearby, Cotacachi close to Cuicocha, and Zumbagua close to Quilotoa. In addition, no recent eruptions were reported during the historical and pre-Columbian times. We aimed to understand the community's organization, the land's use and ownership, the ways of inhabiting the landscape, and the existing awareness of volcanic hazards and risks. To achieve these goals, we looked for the cosmological elements of the relationship between the inhabitants and both volcanoes based on the collection of stories and myths. We also explored the roles of the different actors and their interaction in the territory. In spite of the similar volcanological contexts, we identify very different situations in terms of community organization, links with the government agencies, economic activities and understanding of volcanic phenomena. From our research, we stablished different departing points at both places and hence different outreach strategies should be developed to properly communicate volcanic hazards in each context.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Volcanic Geoheritage of Datça Peninsula, Muğla, Türkiye

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Like other elements of natural heritage, tephra deposits are under the threat of extinction via processes to which human beings can also contribute. We aim to introduce volcanic geoheritage elements of Datça (Muğla), and to make geosite proposals. Muğla region in general, has become by far the most popular destination in Türkiye in terms of both settlement and tourism. In this context, examples of medial tephra on Datça peninsula representing Quaternary Aegean Arc volcanism will be introduced. Medial Kos Plateau Tuff (KPT) deposits, formed by a submarine caldera collapse 161ka ago in the Kos-Nisyros-Yali volcanic system are located on Datça. The KPT is a rare example for the emplacement of large-volume pyroclastic density current travelling across sea and deposited on land. It is thought to be similar to 1883 Karakatau in terms of emplacement, and Tambora 1815 eruption (VEI 7) owing to its volume (110 km^3). As the evidence of this active volcanic system, medial KPT on Datça is important for volcanic risk assessment of southwestern Anatolia, and should be preserved. Another medial tephra on Datça is the pumice fall of Kyra eruption (135 ka) of Nisyros. The andesitic pumice lapilli up to 350 cm thick near Knidos pinches out to 60 cm towards the east of the peninsula. The first precise geochronological data for the pre-caldera phase of Nisyros were obtained from these deposits. Çeşmeköy and Belenköy locations quarried for KPT pumice, and Sındıköy location where KPT and Nisyros Kyra fall units are both observed are proposed as geosites.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Nisyros Aspiring UNESCO Global Geopark: Communicating Volcanic Heritage to Local and Global Audiences

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Nisyros Geopark, located in the Southeastern Aegean, is a candidate for the UNESCO Global Geoparks Network due to its unique volcanic heritage and its integration of geological, natural, and cultural elements. Spanning 481 km^2, it encompasses the active volcano of Nisyros and surrounding islands, forming a natural and cultural mosaic shaped by the dynamics of the South Aegean Volcanic Arc. The geopark encompasses 24 geosites, including active hydrothermal craters, a collapse caldera, volcanic domes, and numerous hot springs along the coastline. In recent years, extensive efforts have been made to highlight and disseminate the volcanic geoheritage of Nisyros, targeting both local residents and a wider audience. Key initiatives include educational programs, workshops, guided tours, and summer schools, which connect people to the island's extraordinary geological and cultural history. The Geopark also leverages modern communication tools, such as mobile applications and its dedicated website (www.nisyrosgeopark.gr), to ensure accessibility and engagement with diverse audiences. The geopark's outreach aims not only to educate but also seeks to strengthen awareness and appreciation of its unique volcanic environment. By fostering partnerships with schools, universities, and cultural organizations, it strives to embed the importance of volcanic geoheritage into the collective consciousness of the local community and visitors alike. The integration of scientific research, cultural traditions, and innovative communication techniques positions Nisyros Geopark as a vital link between the volcanic past and the broader public, ensuring that its geoheritage is celebrated, understood, and preserved for generations to come.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Tangible and intangible cultural values of volcanic geoheritage in the Newer Volcanics Province, Australia: a geosystem services perspective

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It is increasingly recognised that a holistic approach to volcanic geoheritage that considers the interconnectedness of tangible and intangible natural (geological, geomorphological, ecological) and cultural (e.g., aesthetic, recreational, traditional, historic, social and spiritual) elements is key for the success of geotourism and geoconservation. This study presents a geosystem services approach to document and explore the multiple values of volcanic geoheritage in Newer Volcanics Province of Australia, with a focus on its under researched tangible and intangible cultural geoheritage values. This research presents a holistic narrative that fosters a deep appreciation of the intricate links between Earth systems and human culture. The inclusion of cultural values in geoheritage frameworks, contributes to raising awareness of the broader significance of volcanic geoheritage, enhancing its appeal to visitors in urban to rural areas. Furthermore, it provides opportunities for multidisciplinary and multicultural dialogue, enhances geoeducation, and supports culturally aware geoconservation.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Volcanic Geoheritage and Geotourism in Volcanic Geoparks in China

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Geotourism has become more popular in recent decades.Volcanic landscapes and volcanism together can fascinate a general public about the forces of nature. Volcanism has produced devastating natural disasters through human history but has also fostered the course of the evolution of humankind and its societies. Numerous volcanic processes are among those that captivate human minds at every level and provide fundamental information for understanding how the Earth works. China has abundant high quality volcanic geoheritage, which attracts a large number of visitors. At present, 9 UNESCO global geoparks and 20 national geoparks in China are volcanic geoparks. They aim to protect the volcanic heritage, communicate its values, and enhance it with the help of adequate geotourism offers. Geotourism could be an opportunity for rural development, and it could contribute to efforts in alleviating poverty and rural migration. This paper analyzes the characteristics, geoconservation, geoeducation and geotourism of volcanic geoheritage in volcanic geoparks in China, and discusses the main problems such as inefficient conservation management, uncoordinated development, and poor interpretation. In addition, some suggestions have been provided.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Volcanic geoheritage on active volcanic islands (Tenerife, Spain) to promote the geotourism in sun and beaches mass tourism destinations

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^Tenerife´s volcanism as a result of the accumulation of different volcanic materials during the last 16 million years. This complex volcanism creates spectacular landscapes that contain great diversity of volcanic (stratovolcanoes, calderas, shield volcanoes, domes, cinder or scoria cones, hornitos, maars, tuff ring and cones, lava fields, lava delta, volcanic tubes and others minor volcanic landforms) and non-volcanic geoforms associated with erosion and accumulation processes (cliffs, ravines, beaches, dunes, periglaciarism and others). The main aim of this work is to identify the diversity of the geoheritage of Tenerife in order to propose geoconservation strategies and promote geotourism to diversify the island's leisure offerings. In Tenerife it can be recognized different morphostructures: three shield volcanoes (Anaga, Teno and Adeje), two volcanic ridges (Pedro Gil and Abeque), an important volcanic field in the south of the island, a central caldera (Las Cañadas), a complex stratovolcano (Teide-Pico Viejo) and hundreds of cinder or scoria monogenetic cones scattered throughout the island's geography. All of this results in a rich and varied geoheritage that can contribute to strengthening geotourism in Tenerife. To achieve this, it is first necessary to identify the geoheritage and then propose strategies for geoconservation and the promotion of geotourism through georoutes. Finally, the inventory of volcanic and non-volcanic geoforms, the proposal for geoconservation within the natural protected areas, and the establishment of geo-itineraries in both natural and urban spaces will be able to diversify the sun and beach tourism offer in Tenerife.^

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Interconnected initiatives to promote volcanic risk awareness by leveraging geoheritage in Arequipa, Peru.

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In recent years, initiatives have flourished in the Arequipa region (Peru) to promote volcanic risk education through the valorization of geoheritage and cultural heritage. These include: a guided geotourist route and quarry that the *maestro canteros* transformed into a field of sculptures, allowing tourism to support the survival of traditional stone sculpture activities; the recognition of this area as one of the IUGS's first 100 geosites; a short animated film depicting the formation of the Sillar, an ignimbrite deposit formed 1.65 million years ago; a book with the same characters explaining volcanic hazards; an open-access interactive map composed of 360-degree images where locals and scientists describe their environment; exhibitions displaying volcanic tephra deposits in slabs from Misti volcano at the San Agustin University and the Civil Protection Awareness Center in Arequipa; an (audio-)book in Quechua for the Colca and Andagua Volcanoes UNESCO Global Geopark. At first glance, these initiatives may seem unrelated to each other, but they are, in fact, directly connected to at least one other initiative, and sometimes to all of them. We will establish these connections and explain how they enhance the potential for risk awareness, particularly in the city of Arequipa, where over one million inhabitants are directly exposed to the effects of extreme rain events and a potential eruption of the Misti volcano.

Theme: 7. Communication in Volcanology

Session 7.1: From Indigenous Knowledge to Geoheritage: Strengthening Community Resilience and Public Engagement in Volcanic Regions

Allocated presentation: Poster

Indigenous placenames of Alaska volcanoes: accessing hidden information for better understanding and communication about hazards

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Volcanology increasingly recognizes the inherent value of Indigenous knowledge about volcanoes, as evidenced by ongoing collaborative studies and the formation of IAVCEI's new Indigenous Volcanology Network. Indigenous knowledge is intertwined with language and culture, including placenames. Although Alaska contains 229 federally recognized tribes and more than 20 Native languages, some cultural aspects are common across many Alaska Native groups. Alaska Native placenames for volcanoes may be a word or phrase that directly depicts volcanic phenomenon, or, more often, are a coded word or phrase that is shorthand for an oral history story about that place. As a result, placenames that may initially appear to not contain volcanic meaning can instead bear rich volcanological data. However, in-depth knowledge of the language and culture is required to understand the names. For example, the name "Qana-Tanax̂" from Unangam Tunuu means "which island" and refers to oral history about seeing the island rise from the ocean overnight. Knowledge encoded in placenames and oral history can help our understanding of volcanic history, processes, and hazards, and can also improve communication with Indigenous communities concerning volcanic hazards. As part of an effort at the Alaska Volcano Observatory to responsibly learn these placenames and their meanings, we have compiled more than 50 Native placenames for Alaska volcanoes. We are building relationships with Native communities to more fully learn and contextualize these names, improving our understanding of volcanic history, processes, and hazards.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Talk [Invited]

Managing prolonged volcanic unrest in the Reykjanes-Svartsengi system: Challenges in monitoring, hazard assessment and risk communication

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Since October 2023, volcanic unrest has been ongoing in the Reykjanes-Svartsengi volcanic system, Iceland. To date, seven fissure eruptions have occurred on the Sundhnúkur crater row. This type of effusive volcanic activity, characterized by eruptions closely spaced in time, is well-documented in Iceland's eruption history and is referred to as *fires*. The proximity of eruptive fissures on the Sundhnúkur crater row to critical infrastructure, combined with sustained volcanic activity, makes the ongoing unrest a remarkable case study for analyzing hazards and risks. The Icelandic Meteorological Office (IMO), as the State Volcano Observatory, is tasked with assessing volcanic hazards. One of IMO's key roles is to provide decision-makers with hazard-based assessments to minimize volcanic risks. Despite excellent collaboration between IMO and Icelandic civil authorities, the scale, duration, and intensity of the volcanic unrest have necessitated additional responsibilities for IMO. These include: (1) using IMO's published hazard map as the primary tool for regional risk assessments; (2) holding dedicated meetings with private companies to explain the basis of hazard assessments and how potential hazards could disrupt economic activity; and (3) addressing the unilateral governmental decision to reopen the town of Grindavík without an actionable preparedness plan, which required IMO to develop ad-hoc contingency plans for enhanced monitoring and assessment. Alongside an overview of the eruptive activity, this talk will present the challenges faced by IMO personnel in managing a prolonged phase of high uncertainty under significant pressure. It will also highlight how the communication and assessment of volcanic hazards were successfully achieved.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Talk

A new ashfall response poster: Enhancing nautical resilience from Patagonian lakes to broader waters

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Volcanic ashfall events have historically disrupted nautical activities in Patagonia, causing significant damage to ships and ports. Despite the severity of these events, which have included extreme outcomes such as vessel capsizing, there has been a notable absence of guidance to assist nautical operators in responding to volcanic ashfall. This stands in sharp contrast to the extensive support available to other transport and critical infrastructure sectors. Building on lessons learned from past eruptions, including those of Hudson (1991), Chaitén (2008), Cordón Caulle (2011-2012), and Calbuco (2015), we have closely collaborated with local stakeholders to address this gap and release the first version of the response poster, “Volcanic Ash: Advice for the Nautical Sector (Version #1).” The poster offers actionable guidance for ship and port operators, with potential applicability to other navigable areas exposed to volcanic ashfall. It first outlines the hazards specific to water transport systems, including primary fallout and the long-term risk of ash remobilization, which can persist for decades after an eruption. It also summarizes the potential impacts of volcanic ash on critical components of port and vessel systems. Finally, the poster provides practical recommendations for preparation, response, and recovery before, during, and after an ashfall event. The goal of this effort is not only to make this valuable tool available to stakeholders but also to share insights into its development process, highlight the innovative information it contains, and gather feedback from colleagues on crisis management experiences and cases of eruptions impacting ships, ports, and global navigation.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Talk

Ethics in Volcanology: Collaboration, Communities and Commitment

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This paper uses relevant bodies of literature and results from surveys and interviews to examine the challenges and opportunities of a volcanology ethical code. It incorporates insights from geoethics (a growing body of literature that examines the role of ethics in geology more broadly and includes the ethical management of resources, scientific knowledge and disaster risk, among other things), feminist studies (which focusses on the experiences and voices of marginalised groups) and social studies of science (which examines the role of science in and as society). These are combined with results from several surveys and interviews to think through some of the key challenges for volcanologists in the modern research, operational and media landscape. Communities have access to information from many sources, and often lack the skills to discern trustworthy from untrustworthy sources. This places the onus on scientists to think through their own positions, the power dynamics in which they operate and the potential for misinterpretation and misuse of results. There are key considerations concerning how projects are managed, how research interacts with society (e.g. collaboration and the inclusion of observatories, for example), communication practices and who is involved (e.g. what role, if any, do academics have in volcanic crises?), how and when affected communities are engaged with in the research process if at all, and how power dynamics are negotiated both within and beyond the scientific community.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Talk

Using social media for rapid assessment of emotional impacts of volcanic hazards

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Social media posts have been previously used for assessing geophysical aspects of volcanic and seismic events, for example, locating earthquakes; and science communication. They have also been utilized for crisis and risk communication, rapid assessment of material damage, and aiding recovery efforts after several disasters including e.g. the Great Tohoku earthquake. Here we demonstrate how social media can be used as a cost-effective tool for gauging public discourse and the potential emotional impact of volcanic events in near-real time[1]. We used natural language processing (NLP) of Twitter posts to analyse the sentiments expressed in relation to volcanic-seismic unrest, and a subsequent fissure eruption in Iceland 2019-2021. We show that although these volcanic hazards were of small size and caused negligible material damage, they were associated with a measurable change in expressed emotions in the local populations. The seismic unrest was associated with predominantly negative sentiments (positive-to-negative sentiment ratio 1:1.3), but the eruption with predominantly positive (positive-to-negative sentiment ratio 1.4:1). Incorporating sentiment analysis of crowd-sourced information, such as social media posts, into local risk management has the potential for immediate and longer-term benefits. While our method does not provide direct measures of the mental health state and impacts, and is not intended to replace more formal investigations, it may be used to quickly gauge whether communities are under stress and may require additional surveying and/or resources. [1]Ilyinskaya et al 2024 Brief communication: Small-scale geohazards cause significant and highly variable impacts on emotions, *Nat. Hazards Earth Syst. Sci.*, 24, https://doi.org/10.5194/nhess-24-3115-2024.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Talk

Scientific advice to the Italian Civil Protection on volcanic hazard, during the current unrest of the Campi Flegrei caldera

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**presenting and corresponding author* Facing the recent evolution of the Campi Flegrei caldera unrest, the Scientific Advisory Committee (Commissione Grandi Rischi; CGR) of the Italian Department of Civil Protection (DPC) is now managing a very complex and potentially disruptive situation, in the frame of and according to the Italian legislation. At Campi Flegrei, more than 450,000 people live within the caldera floor that is entirely mapped as red zone, i.e. the area that according to the National Emergency Plan needs to be fully evacuated prior to an eruption, with at least 72 hours of anticipation to allow all civil protection activities to be orderly executed. This has created enormous pressure on scientific advice, since missing a full evacuation prior to an eruption may result in a severe toll, as much as a false alarm may cause severe and unnecessary economic and social disruption. Essentially, scientists are required to provide their advice not only to anticipate with certainty the forthcoming eruption, but with enough anticipation for civil protection procedures to be put into place. In this contribution the authors, who are the members of the current CGR, will summarize the scientific advisory activities undertaken since October 2023, the challenges and the proposed innovations respect to previous practices, including the auditing of the international scientific community on several relevant topics. We hope to set off an in-depth discussion about the best procedures to adopt to give timely, scientifically informed advice in areas exposed to extremely high volcanic risks.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Talk

Reframing science advisory: it all starts with a conversation

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There is a persisting romantic view of decision-making whereby authorities and communities have well-defined and well-articulated information needs that guide scientists in their providing of science advice about volcanic hazards and risks. Reality is somewhat different and far more complex, especially in uncertain times, and potentially escalating volcanic crises, or even during peacetime when volcanic risk can be deprioritised over more pressing issues. Some key factors contribute to this complexity. - Decision-making is contextual. Volcanologists tend to view volcanic hazards and risks as the sole determinant for decision-making, whereas it is only one piece of the puzzle. - Decision-making involves both facts and emotions; hence, advisory should be presented in a relatable narrative. - Experiences like the 2009 L'Aquila earthquake and the 2019 Whakaari / White Island eruption have stigmatised science advisory. This has caused anxiety and pushback from scientists to stay clear of risk management, leading to unhelpful passive attitudes or "it is not our role" narratives, fostering communication breakdowns. Authorities keep setting unrealistic expectations of science advisory, while scientists try to determine in semi-isolation the most helpful range of science outputs to provide. This often leads to information overload in technical jargon, leaving authorities and communities with only one question: "what should we do?" Here we draw from decades of volcanic crises to illustrate how reframing our approach to science advisory can make a positive difference. And it all starts with a conversation and two key questions: what decision do you have to make? And how do you make it?

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Talk

Fighting Fire with Faith: Investigating a faith-based response to the 2021 Tajogaite eruption (La Palma, Canary Islands).

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For centuries volcanic eruptions have been labelled so called '*acts of God',* perceived as manifestations of divine punishment or tests of faith. This framing continues to resonate for communities living with volcanic hazards, where religious beliefs influence how volcanic risk is understood and addressed. In these contexts, faith can play a pivotal role in shaping both individual and collective perception of risk, and decision making. Thus, how does faith influence the interpretation of scientific information during volcanic emergencies? How does faith shape decision in the face of volcanic crises? And what might we learn from a faith-based response to volcanic crises? This paper examines these questions, first by literature review, drawing from both Theology and existing case studies in Volcanology. Then this situates these questions in the context of the 2021 Tajogaite eruption in La Palma, presenting preliminary results. The Tajogaite eruption was one of the most destructive eruptions in La Palma's recent history, leading to the evacuation of 7,000 people and the destruction of 1345 homes. The eruption lasted 85 days, however the recovery still continues today, over three years on. Being a predominantly Catholic island - how did faith shape risk perception and decision making? And what can we learn from faith-based organisations who worked on the front line of the eruption? Additionally, there are wider lessons to be learned for how we adapt communication to religious communities across the world, living with volcanic hazards.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Talk

Before I hit "Send": Communicating volcanic hazard in Caribbean SIDS

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The small island developing states (SIDS) of the Eastern Caribbean are home to 21 potentially active volcanoes. SIDS typically have very narrow economic bases that can be severely impacted by hazard events. Shocks to these small economies usually have very dire consequences for island populations and governments that manage perennially scarce resources. Also, small populations often mean relatively few experts available to guide public preparedness and response to natural hazard events. This lack of expert capacity is even more acute for low frequency events like volcanic crises. In these circumstances, volcano scientists invariably work very closely with risk managers who may face significant political pressure. These conditions increase the managerial risks faced by scientists as they can lose credibility and could be legally liable for the negative outcomes. Disaster risk governance frameworks that have not yet developed and legislated binding crisis management protocols also present several other challenges. Here we discuss some of the challenges faced and solutions devised by volcanologists working to understand volcanic hazard and advise multiple governments in the English-speaking Eastern Caribbean. We also use this opportunity to share some of the lessons learnt from experiences leading up to and during the 2020 – 2021 eruption of the La Soufrière Volcano, St. Vincent. Finally, we discuss the value of effective communication between risk management stakeholders during inter-eruptive periods in facilitating sustainable economic development, particularly in small island developing states (SIDS).

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Philippine Case Study on Strengthening Multilingual Volcano Risk Communication

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Risk assessment and risk management are distinct, interconnected functions. In the Philippines' polycentric disaster risk management (DRM) system, volcanic risk assessment is a shared responsibility between the national (Philippine Institute of Volcanology and Seismology) and local governments (Local Disaster Risk Reduction and Management Offices), while the latter is responsible for localized strategies like awareness campaigns and community-based early warning systems. This setting requires close coordination, yet communication gaps persist. Challenges in multilingualism contribute to this problem. Through surveys and focus group discussions, challenges were identified including: 1) diverse languages with varied standardization; 2) dominant languages and minorities; and 3) gaps between expert and public language. These challenges are underpinned by limited capacities. National-level scientists need improved public language skills while local-level officials require technical capacity to cohesively and effectively communicate volcano-related information to communities. It is therefore argued that strengthening multilingualism in volcanic risk communication can lead to more effective DRM strategies. However, several bills have been proposed to mandate plain language and local languages in risk communication but none have been passed. Recently, Republic Act No. 12027 lapsed into law, discontinuing mother tongue instruction from kindergarten to grade 3. This policy environment therefore underscores the urgent need for national laws supporting multilingual risk communication, with clear standards, structures, and functions of the involved institutions. To achieve this, scientists from warning agencies can take a more active role in identifying policy issues and solutions, working closely with the local partners, academia, and policymakers to develop effective legislation.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

How to deal with a long recurrence rate volcanic hazard of dispersed volcanic fields with high geoheritage values? Geohazard in a geoheritage context

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Western Saudi Arabia has one of the largest monogenetic volcanic provinces on Earth (~3500 volcanoes since the Pleistocene in 19 fields). The youngest eruption occurred in the, now rapidly growing, Madinah City in 1256-CE, but Holocene eruptions are also suspected elsewhere. Earthquake swarms accompany the magma flows beneath the volcanic fields. These regions are dispersed fields with low number of age data to define recurrence rate hence probabilistic eruption forecasting has high uncertainty beyond the expected time scale of decades for modern developments. The region has significant volcanic geodiversity. Communicating volcanic hazard while growing temptation to exploit the geoheritage for tourism is difficult. A project by the Red Sea Global, a major development company of Saudi Arabia, at the Quaternary Lunayyir Volcanic Field (~700 vents from ~150 edifices over ~600-ka) faced with a complex problem how to deal with high uncertainty of complex volcanic-seismic hazard to protect future development sites and visitors but also to be able to utilize the benefit of the high value geoheritage and keeping it preserved under conservation strategies. The Saudi Geological Survey and the Red Sea Global co-developing a strategy where volcano-seismic hazard estimation is combined with the geodiversity calculation, geosite recognitions within a sustainable geoconservation for tourism purpose and geoeducation. In this approach volcano-seismic hazard mapping is impacted by geoheritage mapping by characterising their values to provide data for decision-makers to outline management scenarios and communication strategies alongside with co-shared hazard and heritage mitigation strategies for development sites on active monogenetic volcanic fields.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

A Volcanic Risk Ranking for Ecuadorian Volcanoes: Are 10,000 years enough to recognize the difference between risk and hazard?

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Ecuador has a high concentration of volcanoes along the Andean Cordilleras and volcanoes in the Galápagos Islands. Recently, different eruptive events occurred at volcanoes Guagua Pichincha (1999-2001), El Reventador (2002-present), Tungurahua (1999-2016), Sangay (2019-present), and Cotopaxi, (2015, and most recently from October 2022 – July 2023). Recent eruptions have also occurred on the Galapagos Islands (e.g., Wolf in 2015, Fernandina (2024), and Sierra Negra in 2018). Frequent eruptions and impacts include adverse health effects, loss of life, societal disruption, and economic losses at local and regional scales. We employed a new methodology to determine volcanic risk ranking proposed by Nieto-Torres et al. (2021) to analyze 39 Ecuadorian volcanoes that presented eruptive activity during the last 10,000 years. The Volcanic Risk Ranking (VRR) in Ecuador includes the traditional 3-factor (Hazard, Exposure, and Vulnerability, VRR 1) and the 4-factor (Hazard, Exposure, Vulnerability, and Resilience, VRR 2). Consequently, the top VRR 1 and VRR 2, are Cotopaxi and Atacazo-Ninahuilca, respectively. Volcanoes on the sparsely-populated Galapagos Islands show lower risk scores in both methods. The results of a collaborative framework involving multidisciplinary teams and inter-institutional cooperation at national and international levels, an assessment of early warning systems, and other measures are required to reduce future impact in terms of volcanic risk. However, we are still working on generating space to discuss those topics and looking for a consensus is essential. Then, effective communication can occur, directly influencing disaster preparedness and response planning and reducing vulnerability to volcanic hazards.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Communication of volcanic hazard and risk for Decision Making: Lessons Learned from Geohazards studies For Tsunami And Other Geo-Disasters along Coastal Regions.

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South Asia is more vulnerable to Geo disasters and impacts of climate changes in recent years. On 26 December 2004 massive waves triggered by an earthquake surged into coastal communities in Asia and East Africa with devastating force. Hitting Indonesia, Sri Lanka, Thailand and India hardest, the deadly waves swept more than 200 000 people to their deaths. To mitigate geo-disasters, marine hazards and rehabilitation during post tsunami period, scientific knowledge is needed, requiring experienced research communities who can train the local population during tsunami rehabilitation. ISDR, AVCCE, India and IAPSO International Commission on Ground water–Sea Water Interactions (CGSI) and Open University Geology Society, UK (OUGSME) jointly started the initiatives on the problem identifications in management of risks in geo-disasters, tsunami rehabilitation, to investigate problems related to social-economic and ecological risks and management issues resulting from tsunami and Geo-disaster, to aid mitigation planning in affected areas and to educate scientists and local populations to form a basis for sustainable solutions and decision making. The presentation aims to assess the potential risk, hazard, problems and damage arising from Tsunami in the Asia-pacific and Europe, coastal ecosystems. This presentation reviews the issues of Geo-risks communication, marine-risks communication and decision making along coastal region of Asia-Pacific and also human influence on the earth system. The recommendations from the experts signify strengthening the cooperation among UNESCO, IUGS, IAHS, Governmental organizations and international organizations for capacity building of local population, scientists/researchers for integration of Geohazards Studies on vulnerability and risk assessments along coastal regions.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

How to frighten people with impending eruption in a country with no active volcano? The shared responsibility of media and scientists

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With the advent of new and powerful social media networks and of the emergence of science influencers as an extremely effective science divulgation tools became readily available to spread ideas spontaneously at global, regional and local scale, commonly for the sake of own carrier ambitions. Volcanology and volcanologist are not immune to such temptations. A case study conducted in Eastern Europe may convincingly illustrate this trend. The Pleistocene Ciomadul volcano in Romania whose last eruption occurred ca. 28.000 years ago, was since 2015 the focus of repeated alarming news in the Romanian and Hungarian, as well as in the English-language media (including Smithsonian Institution's and Scientific American's outreach webpages). Starting from scientific papers published, a group of researchers, eager to popularize their work and results, initiated media interviews whose published texts wildly distorted and exaggerated those results in the sense that the volcano is ready to erupt. Titles such as „*A volcano in Romania, considered extinct, seethes on the verge of eruption*" (in Romanian), "*Without warning*", "*Warning. Ciomadul volcano can erupt again*!", "*If the Carpathian volcano awakens, that will be devastating*" (in Hungarian), "*Magma found simmering under an 'extinct' volcano. Here's what that means*" (in English) had a strong emotional impact on the people living in the volcano's proximity. These alarming media reports was rarely denied or corrected by the scientists involved. By contrary, despite this experience, they repeatedly fuelled the media portals invoking their newly published papers, some of them including the misleading wording "apparently extinct" in their titles.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Volcanic Wisdom: Strengthening Global Resilience Through Enhanced Multi-Hazard Early Warning and Alert Level Systems

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This research aims to enhance global preparedness for natural multi-hazard events by leveraging the volcanological community's experience with the Volcanic Alert Level System (VALS). With the growing intensity of natural hazards felt globally, there is an increased need for robust Early Warning Systems (EWSs) and Alert Level Systems (ALSs) that assist in mitigating the detrimental effects of natural hazards on communities. Despite international efforts, current EWSs and ALSs lack integration across multiple hazard types and geographies, leading to insufficiencies in hazard communication and risk management. Additionally, numerous EWSs and ALSs are employed globally for varying hazards, yet there is limited literature on these systems' current design and implementation. Conversely, volcanoes, which pose a wide range of threats over different geographic and temporal scales, have well-developed ALSs and EWSs that necessitate the consideration of multiple hazards concurring and/or compounding. The volcanological community's use of VALSs offers a rich case study for improving current multi-hazard ALSs and EWSs. Globally, VALSs have been utilized to varying success to communicate volcanic risks, yet there is limited scientific analysis of the operational efficacy of these systems. My research aims to fill this gap by conducting a comprehensive global survey of VALSs, analyzing their design, implementation, and effectiveness to inform broader multi-hazard EWS and ALS development. By leveraging the extensive experience of the volcanological community in dealing with anticipatory issues from multi-hazard events and the use of diverse warning systems, more effective global EWSs and ALSs for multi-hazard events can be produced.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Surveying Visitors at Askja Volcano, Iceland

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Askja is an active volcano in the Icelandic highlands that brings hundreds to thousands of tourists to see its unique landscape. This study utilized a voluntary 14-question survey developed in partnership with the Vatnajökull National Park (VNP) to determine how aware tourists are at a remote, active volcano in Iceland. The survey was posted from July 20 to October 1, 2024 using a QR-code at various locations around Dreki at Askja and available on an iPad managed by a team of two individuals based at the Dreki huts from July 29 to August 9, 2024. The primary goals of this survey were: 1) to see if the methods were viable for future volcano tourism surveys, 2) to determine how tourists access information in the VNP, and 3) tourists' preferred form of communication of potential volcanic hazards. This study was able to determine that a survey is a viable method for evaluating how tourists engage with information in the VNP. The data surrounding health and safety questions shows that 26% of tourists do not know the medical emergency number in Iceland. One of the main avoidable hazards at Askja is hiking to and swimming in maar lake, Viti. However, 23 individuals admitted to hiking down into or swimming in Viti, and 87% of them indicated they had seen the VNP hazardous conditions warning sign. To communicate volcanic hazards at tourist sites in Iceland, additional surveys are needed to understand and implement ways to communicate to the varied populations at these sites.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

The possible factors contributing to fatalities and injuries during the 2019 Whakaari/White Island disaster in New Zealand

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Volcanologists play a technical role in monitoring and predicting volcanic eruptions. However, as experts, they also have an ethical responsibility to protect lives and property, through advice they give to governmental authorities regarding the dangers, hazards and risks associated with particular volcanoes. The 9th December 2019 explosive eruption of Whakaari/White Island volcano offshore from Whakatane in New Zealand killed 23 tourists and guides, and caused injuries, some life long, to 24 others. Why did authorities allow tourism to and *inside* the crater of this highly explosive remote island volcano? Did the volcanological community adequately inform and warn authorities of the dangers and likelihood of such a deadly eruption occurring when tourists were on the island? Were tourists adequately warned and informed of the history of the volcano, the hazards, dangers and risks faced? Was allowing tourism to Whakaari in support of the local tourism industry a contributing factor? Were tourists advised that if they were killed or injured, litigation against tourism companies and government agencies could not be undertaken because of New Zealand's archaic No Fault public liability policies? Since most tourists are not educated volcanologists, nor lawyers, it is absurd to argue that tourists undertook trips to Whakaari fully informed, because they could not have known of the actual hazards, dangers and risks; not even the guides knew. In summary, how on earth were tourists allowed to go on authorised tours into the crater of a highly explosive volcano from which there was no escape?

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Asserting the role of volcano observatories in the context of Sendai commitments and Early Warnings for All

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Nations of the world are committed to improving multi-hazard early warning systems (MHEWS) under the Sendai Framework for Disaster Risk Reduction 2015-2030. In 2022, the UN Secretary General additionally announced a major push towards achieving global reach of MHEWS under the Early Warnings For All initiative. Most attention for MHEWS is directed towards hydrometeorological events, but it is essential that volcanic risks are well managed due to the certainty of future events with the potential for significant to catastrophic impacts. How will we achieve this? The international aviation community already sets global requirements and recommendations for volcanic monitoring, and the marine and tsunami communities are increasingly developing better standards and recommended practices. To these can be added national best practices for disaster management, agriculture, land transport and other sectors to articulate an *integrated* concept for what the world needs from volcanology. Gap assessment tools have been developed for meteorology that can be adapted to assess needs and practical actions for volcanology, including legislative mandates, professional staffing levels, standards and competencies, training and research, data, and quality-managed operations to support MHEWS best practices with respect to volcanology. Most importantly, development of global coordination and resource-sharing arrangements will enable equitable practical implementation of improved volcanic hazards assessment and mitigation despite inequitable resourcing around the world. The role of IAVCEI, working with UN bodies, is critical in this process. A workshop will explore many of these issues immediately after the IAVCEI Scientific Assembly.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Explosive eruptions at French overseas volcanoes: Simulation and integration into volcano emergency plans

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For the first time, all the French monitored volcanoes exhibit signs of unrest. In the Lesser Antilles, the level of volcanic activity is now yellow-Vigilance (2 out of 4 on the alert scale) for both Montagne Pelée (Martinique) and La Soufrière (Guadeloupe). In the Comoros archipelago (Indian Ocean), the 2018-2020 Fani Maoré eruption confirms the reactivation of the whole magmatic system in Mayotte. Field-based studies on these volcanic systems show that their eruptive histories include several explosive eruptions ranging from hydrovolcanic to Plinian eruptions. In this context, the authorities of Martinique and Guadeloupe revised the volcano emergency response plans for Montagne Pelée in 2022 and La Soufrière in 2024, while the Prefecture is working on a first version for Mayotte. Here, we present the hazard maps for tephra fallout elaborated using the HAZMAP model, when considering either a hydrovolcanic or a sub-Plinian/Plinian eruptive scenario at Montagne Pelée, La Soufrière and Mayotte. For each volcano, we performed single-scenario (based on historical eruptions), multiple-scenario (including 43 years of wind data) and probabilistic hazard maps. We present how these results were shared and evaluated with the authorities in Martinique and in Guadeloupe to improve the efficacy and relevance of the maps, and their use in volcano emergency exercises that were organized by Civil Protection authorities in conjunction with French scientists in Guadeloupe (2019, 2021) and Martinique (2022, 2023). These discussions led to the incorporation of the two scenarios considering multiple phenomena into the revised plans for Martinique and Guadeloupe, and soon for Mayotte.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Science advice for enhanced spatial planning in volcanic regions

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This contribution builds on an experience held within the Scientific Advice Mechanism of the European Commission elaborating a Scientific Opinion (SO) to inform European policies on Strategic Crisis Management. The SO tackles also the issue of how to provide scientific advice not only during a crisis but along the entire timescale, from anticipation to response and recovery. It encourages a long term view even when dealing with impeding threats complementing resilience and disaster risk management. This contribution addresses science advice for spatial planning, both as a preventative non-structural mitigation measure and for recovery and reconstruction. Literature on the topic is rather scant for several reasons including the objective difficulties in reducing exposure and vulnerabilities in densely populated cities and the lack of competence of planners. One important reason lies in the scale and type of provided science advice frameworks. Advice should be given both at national/regional and local scale. At the former to inform legislation on urban and land use planning and on strategic environmental impact assessment to embed volcanic hazards' avoidance as a key concern. At the local level, scientific advice bodies must include diverse disciplinary backgrounds, not only to inform about volcanic hazards, but help in visualizing the implication of estimated impacts and probabilities on urban functions and assets to be located or relocated. Required expertise should also cover how to carry out participatory approaches convincingly embedding scientific knowledge on volcanic risk, and how to stress test spatial plans for resilience, as some communities have started to do.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Hazard and risk assessment for fault movements on the Reykjanes peninsula, Iceland

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Significant fault movements related to dike intrusions have been documented, e.g. in Iceland, Hawaii, and Ethiopia. The latest such events occurred on the Reykjanes peninsula, Iceland during an ongoing volcanic unrest. Nine dike intrusions formed from November 2023 to December 2024 of which seven led to fissure eruptions. The intrusions were in some cases accompanied by meter-scale movements along faults. Graben subsidence occurred in the town of Grindavík, where fault movements and subsidence caused significant damage to houses, roads and other infrastructure. An eruption in Fagradalsfjall in 2021 started a new eruptive period on the Reykjanes peninsula, after a hiatus of ~800 years. Previous research indicates that when one volcanic system on the peninsula starts erupting, several of the five others tend to follow within a timescale of tens to a few hundreds of years. Therefore, the Icelandic Meteorological Office is leading a volcanic hazard and risk assessment for the entire Reykjanes peninsula, of which fault movements are considered an important factor. The project is done in collaboration with municipalities, civil protection departments and companies/institutions responsible for maintaining important sources for inhabited areas on the peninsula, e.g. electricity, hot and cold water. Various critical infrastructure is located within the volcanic systems of the Reykjanes peninsula, such as high-temperature geothermal power plants and cold water supplies for larger towns, e.g. part of the capital area of Reykjavík. The hazard and risk assessment includes information on the location of faults and an attempt to estimate the likelihood that they will be reactivated.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Regulatory Sciences, a way of clarifying the roles and responsibilities of researchers in their missions?

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Jurists do not have many examples of researchers' liability for natural hazards. This is quite a new topic inside courts and is hardly addressed in legislation. It was only with the 2012 trial following the deadly Aquila earthquake in 2009 that Italian judges recognized such a responsibility. Later, the conviction in New Zealand of the research institute GNS Science on March 1, 2024, following the Whakaari / White Island eruption, confirmed the legal consecration of the responsibility of researchers in matters of natural hazards. These two cases reflect the researcher's role in disseminating scientific information, and the reasons why their liability is recognised in the context of telluric hazards, which are the only natural hazards that give rise to litigation and, therefore, to a legal analysis. In this context, it appears that the respective legal responsibilities of volcanologists, who have a scientific expertise, and of public authorities, that make decisions, do not seem clearly defined. Our work aims to adapt a concept defined in the United-States of America, which allows to take into account those recent evolutions in the practice of research. This is commonly defined as the "regulatory science", which distinguishes fundamental academic research from operational research aimed at producing legal standards. Adopting this system would both protect researchers in the conduct of their research and would ensure a higher level of guarantee in terms of natural hazard prevention.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Volcanic Risk Perception in the city of Olot (Garrotxa Volcanic Field, Catalonia)

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Population growth in volcanically active areas increases the threat of eruptions, yet monogenetic volcanic systems like the Garrotxa Volcanic Field (GVF) in Catalonia are often overlooked in risk assessments. Despite the absence of recent eruptions—the last one occurring in the early Holocene—the GVF remains geologically active. However, misconceptions persist among residents, fostering a false sense of security and reducing risk awareness. This study examines volcanic risk perception among Olot residents, the central city of the GVF. Surveys, including structured and semi-structured questionnaires, were conducted to assess understanding of volcanic risks and perceived vulnerability to potential volcanic threats. The final aim is also to identify and assess those factors shaping risk awareness. Factors analyzed include technical knowledge, narratives about hazards, trust in authorities, preparedness levels, and demographic variables such as age, education, and socioeconomic status, among others. Preliminary results indicate significant correlations between technical knowledge, preparedness, and trust in authorities, highlighting gaps in current risk communication strategies. This work emphasizes the interaction of social, cultural, and individual factors in shaping risk awareness. By addressing these gaps, this research provides actionable recommendations to improve risk communication, enhance preparedness and risk awareness, and strengthen resilience in communities within monogenetic volcanic fields.
We are grateful to the Espai Cràter, the City Council of Olot, and the Parc Natural de la Zona Volcànica de la Garrotxa for their support. This study is partially funded by the project "Living among volcanoes" (FCT-23-19352) and the BECAS CHILE- ANID, Beca Doctorado en el Extranjero, convocatoria 2022/Folio 72220257.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Lahar Ready: Enhancing Communication of Lahar Hazard around Mt Rainier, USA

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The rugged, unstable, and ice-capped summit of Mt Rainier, Washington State (WA), USA, is a stark reminder of what has come before. Over the last ten thousand years the landscape around Mt Rainier has been dramatically modified by major (10^7-10^8 m^3) lahars at least sixty times. Caused by syn-eruptive sector collapses and pyroclast-ice interactions, or, perhaps, large non-eruptive slope failures, these lahars have been among the largest known to have occurred on Earth. Today, approximately 150,000 people live on the valley floors made up of the deposits of previous lahars. Engagement with at-risk communities in potentially affected valleys has revealed a broad lack of awareness with respect to both active volcanism at Mt Rainier and the possibility of catastrophic lahars. The Lahar Ready initiative is a collaboration between scientists (USGS/University of Washington) and emergency managers in Pierce County, WA. Our aim was to co-produce new, accessible lahar hazard communication materials designed to engage and educate the public about lahar hazard, preparedness measures, and evacuations more effectively. In this presentation, we will share: 1) the insights we gained from collaboration with emergency managers and the public, 2) the designs of our new lahar hazard communication materials, and 3) results of pre- and post- intervention surveys assessing the effectiveness of these materials for increasing lahar hazard awareness and preparedness within at-risk communities.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

A call for consistency: defining. "Erupting, Active, Dormant, and Extinct" volcanoes

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Whether a volcano is considered erupting, active, dormant or extinct, creates different public perceptions of risk. However, these terms do not have clear definitions and they are used differently across contexts. Here, we review the current definitions, and additionally solicit opinions from experts with a goal of a consensus for the volcanological community. We discuss a range of expert opinions collected from online and in person surveys, using quantitative and qualitative methodologies. Our discussion will include the definitions of; 1. an “erupting” volcano and how this is tied to alert level differently between risk management systems, 2. an “active” volcano, which varies between a volcano that has erupted in the Holocene (the last 11,700 years and counting) or a volcano with historical eruptions, 3. a dormant volcano which is a volcano that hasn’t erupted in “a long time” but is expected to again, and 4. an “extinct” volcano that is not expected to erupt again. These definitions cover a large and variable range of time that can cause confusion in scientific and public literature. For example, dormant volcanoes significantly overlap with the current definitions of active, which is further completed by the size of the magmatic system which controls the longer it may be restless before becoming extinct. We will additionally explore how the Volcanic Activity Index (Giordano and Caricchi, 2022), and other expert solutions could address these inconsistencies and provide guidance to re-define active, dormant and extinct volcanoes to facilitate clear communication and decision making.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Exploring Anticipated Evacuation Behavior Among Parents around Mt Rainier, USA

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Mt Rainier, a heavily glaciated stratovolcano within Washington State, USA, has a history of generating major lahars. The ongoing possibility of high-magnitude flows poses a substantial threat to ~150,000 people downstream, necessitating one of the most dense monitoring networks in the USA. This network includes a purpose-built lahar detection system within some radial valleys as portions of the mountain's west flank comprise unstable, hydrothermally altered rock that renders these catchments vulnerable to a "no-notice" lahar derived from a sudden, non-eruptive slope failure. Consequently, for over 20 years, local schools have performed lahar evacuation drills which are now legally mandated. These have demonstrated that the most effective way to remove students from the lahar inundation zone is on foot. However, parents of school children have reported intentions to retrieve their children during an emergency situation, regardless of evacuation recommendations. Such behavior would place parents in harm's way and obstruct the emergency response. In areas where lahar arrival times are very rapid (<1 hr), parent behavior is an essential consideration for the success of city-wide evacuations. While many studies have discussed lahar hazards, preparatory efforts, and expected behavior in the region, the rationale behind parents' intentions during school evacuations remains poorly understood. Here we present survey results examining factors contributing to decision-making among this demographic. Surveyed topics include personal perceptions, resources (e.g., food/water/shelter) at evacuation sites, and family reunification plans. These results may help emergency managers better understand and meet the needs of parents in these vulnerable communities.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

A long-term volcanic hazard and risk assessment for the Reykjanes peninsula, Iceland. Overview and communication with stakeholders

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A new eruptive period has started on the Reykjanes peninsula. From 2021-2024 ten volcanic eruptions occurred in two of the six volcanic systems in the area. History tells that most or all the peninsula's systems become active during eruptive periods, which may last ~500 years. Hence, volcanic eruptions near the most densely populated area in Iceland, including the capital city, are a realistic possibility. It is vital to identify vulnerable areas exposed to volcanic hazards through hazard and risk assessment. The assessments are important for community and urban planning, and a necessary knowledge for reasonable mitigation actions for critical infrastructure such as water supply, power lines, and roads. The Icelandic Meteorological Office, on behalf of the Icelandic government, leads volcanic hazard and risk assessment for the Reykjanes peninsula. Hazard assessment of lava, gas, tephra, earthquakes and fault movements will be completed for the entire area whereas risk assessment is done based on realistic risk scenarios of high impact events, for infrastructure and/or society, useful for response and mitigation planning. The overall aim is to make the society better prepared and resilient to volcanic hazards for centuries to come. Stakeholders participate in the project through regular meetings with IMO, to ensure good understanding between actors and clear and beneficial results for the wider user community. These meetings are organised by civil protection departments and representatives from municipalities and those responsible for critical infrastructure participate. Final products of the project will be made available and communicated through an interactive web portal.

Theme: 7. Communication in Volcanology

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Allocated presentation: Poster

Volcano tourism: a reflection from an IAVCEI working group

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In recent decades, volcano tourism has become very popular including visits to active, dormant, and extinct volcanoes. As more people visit volcanoes, the risks associated with these areas also increase. To attract visitors, tourist operators offer a diversity of tours with varying degrees of difficulty and risk. The most popular attractions include visits to glowing lava flows and fumarolic areas, as well as observing mildly explosive eruptions. The commonality between all visiting options is that many people, sometimes involving multiple and diverse groups, may be exposed to the same volcanic hazard and that individual tourist risk can be very different from the societal risk based on multiple group visits. While individual risk is related to the exposure time of an individual, societal risk is related to the total numbers of visitors, the number of groups and the summations of exposure times. The difference between individual and societal risk can be large with major implications and associated potential decisions. In order to improve communication and awareness of environmental volcanic hazards, related risks recommendations, IAVCEI can provide the public with a collection of best practices and protocols to be checked before planning and embarking on a tour. This aim is to complement existing communication protocols established in each country, without interfering with them. In

addition, IAVCEI may foster interactions with tourism agencies to support effective risk management and improve information dissemination, starting from the role of the volcanologists and volcanological observatories.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Canary Islands Volcanic Risk Reduction Strategy

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The Canary Islands are the only Spanish territory exposed to volcanic risk. The recent eruption on La Palma has highlighted the exposure and vulnerability of our society to volcanic hazards. As a result, the Tajogaite eruption (2021) should mark a turning point in our management of volcanic risk in the Canary Islands, despite the progress made in the last 25 years to reduce volcanic risk in the archipelago. This new direction should be adopted through a Canary Islands Volcanic Risk Reduction Strategy, an operational tool that serves as a framework for addressing and responding to the challenges faced by the Canary Islands due to volcanic risk. It would also serve as a driver and coordinator of various sectoral policies and as a means of raising awareness among citizens, businesses, and administrative bodies. Three basic ideas or pillars (scientific knowledge, public engagement, and consensus) will serve as the foundation for the development of this important tool. Citizen participation would involve inviting all sectors of society that can and should play a role in volcanic risk management (scientists, public administration authorities, politicians, emergency experts, land-use planners, journalists, etc.). The idea behind broad citizen participation is that each sector can debate and provide its perspective on volcanic risk management. The strength of this debate, through a SWOT analysis, lies in the fact that only those observations emerging from consensus can be described. In summary, our society needs a Canary Islands Volcanic Risk Reduction Strategy because volcanic risk is increasing in our archipelago.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Theory and reality in adopting best-practice guidelines during a volcanic crisis

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Guidelines to recommended best practice during volcanic emergencies are easy to support on paper, but less so when an emergency strikes – particularly if this occurs after a lull of several decades. Such intervals are long enough to forget the lessons from previous crises. When a new crisis develops, therefore, individuals may not automatically follow the recommendations, especially if responding to an emergency for the first time. The first crisis at Campi Flegrei in four decades provides a topical case study. West of Naples in Italy, the volcano is home to more than 360,000 people. Following intense volcano-tectonic seismicity in September-October 2023, a report on 09 November in southern Italy's leading newspaper, *Il Mattino*, cited the opinions of "anonymous volcanologists", who claimed that selected (and peer-reviewed) analyses recently presented to Italy's Major Risk Committee were "based on fundamental errors" and "incorrect data" and that they were the results of models – which are "only theories and [often] wrong". The claimants had "not been present at the meeting". They also offered no evidence to justify their criticisms. A predictable outcome was the corrosion of public trust in scientific information. Even if the criticisms were well-intentioned and the consequences of media engagement unexpected, the lack of supporting evidence meant that opportunities were missed for enhancing the collective interpretation of the volcano's unrest. Moral imperatives for scientists during crises are thus not only to be careful in communicating with non-scientists, but also to engage in the constructive testing of ideas among colleagues.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Modernizing Volcanic Hazard Communication: Open-Source Posters Bridging Science, Art, and Global Outreach

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In the late 1990s, the USGS developed a series of illustrations that have since become widely used by both volcano hazard practitioners and academics to discuss the spectrum of volcanic hazards and monitoring techniques. Building on this legacy, we present two open-source posters created in collaboration with Rocksonpaper®, a geoscientist and artist, to modernize and expand these educational tools. The first poster highlights the range of volcanic hazards and state-of-the-art monitoring methods, while the second illustrates the diversity of volcanic eruption styles and the corresponding volcaniclastic deposits they produce. The visually engaging and scientifically accurate artwork is designed to benefit a wide audience, including the general public, students, and hazard practitioners, by fostering a deeper understanding of volcanic processes, primary and secondary hazards, and current monitoring strategies. A key addition in this project is the explicit inclusion of often-overlooked phreatic/hydrothermal and phreatomagmatic/hydrovolcanic processes, which are critical to hazard assessment. We aim to produce multiple language versions of these posters to maximize their global reach and practical utility, ensuring that scientists, volcano hazard practitioners, and the general public worldwide can access and benefit from this resource.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

Volcano tourism at Villarrica Volcano: a first compromise between private operators, volcanologists and authorities

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Chile has advanced significatively in the understanding of volcanic activity and their impacts on population and infrastructure. Currently, a segment of more than 2,000-km-long of the Andean arc is covered with instruments and hazard maps have been developed in more than 30 volcanoes. In the last decade, at least three moderate-size explosive eruptions have been monitored giving timely volcanic alert levels that have allowed to prepare the population and authorities, and several other minor volcanic cycles have been closely supervised. SERNAGEOMIN is the official institution that monitors the volcanic activity and develops hazard assessments in Chile, and therefore is expected to provide alerts with respect to volcanic activity and eruptions. However, we lack enough data to build conceptual models to better understand small events and we are still far from delivering early warnings for small eruptions, which have clear impacts, for instance, on tourism. Recent examples occurred at Láscar and Villarrica volcanoes between 2022 and 2024. The new legislation in Chile allows regional authorities to establish restricted or exclusion zones around the volcanic areas when volcanic activity is increasing. Consequently, in recent years the relationship between public agencies and private operators has become very complex. In this contribution, we show the evolution of this problematic, focused on Villarrica an open-conduit system and the highest-risk volcano in Chile, where a compromise between tourist operators and authorities has been reached, in terms of awareness of volcanic and hazards and ascent protocols.

Theme: 7. Communication in Volcanology

Session 7.2: The role of volcanologists in communicating hazard and risk for decision making

Allocated presentation: Poster

A Volcanic Risk Ranking for Ecuadorian Volcanoes: What is enough to recognize the difference between risk and hazard?

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Ecuador has a high concentration of volcanoes along the Andean Cordilleras and volcanoes in the Galápagos Islands. Recently, different eruptive events occurred at volcanoes Guagua Pichincha (1999-2001), El Reventador (2002-present), Tungurahua (1999-2016), Sangay (2019-present), and Cotopaxi, (2015, and most recently from October 2022 – July 2023). Recent eruptions have also occurred on the Galapagos Islands (e.g., Wolf in 2015, Fernandina (2024), and Sierra Negra in 2018). Frequent eruptions and impacts include adverse health effects, loss of life, societal disruption, and economic losses at local and regional scales. We employed a new methodology to determine volcanic risk ranking proposed by Nieto-Torres et al. (2021) to analyze 39 Ecuadorian volcanoes that presented eruptive activity during the last 10,000 years. The Volcanic Risk Ranking (VRR) in Ecuador includes the traditional 3-factor (Hazard, Exposure, and Vulnerability, VRR 1) and the 4-factor (Hazard, Exposure, Vulnerability, and Resilience, VRR 2). Consequently, the 3 factors-ranking and 4 factors-ranking, are Cotopaxi and Chachimbiro, respectively. Volcanoes on the sparsely populated Galapagos Islands show lower risk scores in both methods. The results of a collaborative framework involving multidisciplinary teams and inter-institutional cooperation at national and international levels, an assessment of early warning systems, and other measures are required to reduce future impact in terms of volcanic risk. However, we are still working on generating space to discuss those topics and looking for a consensus is essential. Then, effective communication can occur, directly influencing disaster preparedness and response planning and reducing vulnerability to volcanic hazards.

Theme: 7. Communication in Volcanology

Session 7.3: Advancing equity and diversity for a more inclusive future in volcanology

Allocated presentation: Talk [Invited]

Disproportionate impacts of the COVID-19 pandemic on early career researchers and disabled researchers in volcanology

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The COVID-19 pandemic has brought unprecedented challenges to researchers worldwide, and extensive studies have demonstrated that its impacts since March 2020 have been unequal. In 2023, as we navigate the post-pandemic times, questions persist regarding potential disparities and enduring effects faced by volcanology researchers, whose activities range from field work in remote areas to laboratory experiments and numerical modelling. In this study, we explore the multifaceted impacts of the pandemic on volcanology researchers through an online survey distributed globally from January to March 2023. Our survey findings reveal that a considerable fraction of volcanology researchers (44%–62%) face longer-term challenges from the pandemic that continue to impact their research, with a notably higher proportion among early career researchers (62%) and researchers with disabilities (76%). In addition, over half (52%) of all surveyed researchers indicated that they had left or considered leaving academia due to pandemic-related factors. A significantly higher proportion of disabled researchers (56%–70%) had left or considered leaving academia compared to researchers without disabilities (42%). Our findings underscore the pandemic's long-lasting and disproportionate impacts on early career and disabled volcanology researchers. We emphasis the need for concerted efforts by research organisations and funding bodies to mitigate the pandemic's enduring impacts, and stress the importance of making conferences accessible to support disabled researchers' participation. As the pandemic's long-lasting impacts ripple across the broader scientific community, the insights from this research can be used for fostering equitable practices and shaping policies beyond volcanology to other research disciplines.

Theme: 7. Communication in Volcanology

Session 7.3: Advancing equity and diversity for a more inclusive future in volcanology

Allocated presentation: Talk [Invited]

Towards Inclusive Collaboration in Volcanology: Guidelines for Best-Engagement Protocols in International Collaboration

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Volcanology is a multidisciplinary science of global interest with specific societal applications in early warning, hazards evaluation and disaster risk reduction and management. Due to its multidisciplinary nature, developments in volcano science are often rooted in collaboration between scientists of various disciplines, often for the goals of geoscientific research, technology development and application and/or capacity-building. Moreover, applied volcanology is also marked by collaborations between scientists and various stakeholders. Collaboration is therefore key in advancing volcanology, both at national and international levels, and may occur between academic institutes, volcano observatories, geological surveys, private or public companies, etc. The International Network for Volcanology Collaboration (INVOLC) is an IAVCEI network with the specific ambition to enhance volcanology globally through improved international collaboration. IAVCEI–INVOLC was created with a focus on volcano scientists working in resource-constrained contexts, including those based in low- or middle-income countries. After a community-wide online survey and inaugural workshop during which INVOLC's ambitions were discussed, a series of challenges, as commonly experienced by those working in resource-constrained settings, were identified. These challenges may present barriers to participation in volcano science in an international context and are related to both organisational resources and inclusion in research collaborations. We present a series of guidelines for best-engagement protocols in international collaboration in volcanology, that may be adopted during times of quiescence, volcanic unrest and/or an eruption and its aftermath. Our aspiration is that these guidelines will help build more respectful, equitable and sustainable partnerships that will ultimately advance the science of volcanology.

Theme: 7. Communication in Volcanology

Session 7.3: Advancing equity and diversity for a more inclusive future in volcanology

Allocated presentation: Talk

Removing the barrier of uncertainty in field courses

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The Earth Sciences have traditionally relied on field excursions as experiential training for undergraduate and graduate students. Although these opportunities can provide important opportunities to learn about primary data collection and field processes, they can also be challenging learning environments regarding logistics and accessibility, limiting participation and educational benefits for diverse student groups. In an effort to ensure that field components of courses at the University of Oregon are inclusive, equitable, and accessible, we created a combination of policies and templates for instructors to use before and during field excursions. Elements of these procedures include: (1) pre-field trip surveys for students to broadly share expectations, background, accessibility limitations, and concerns; (2) detailed field trip narratives with emergency contacts, communication availability, food and water information, gear lists, field locations, cultural information, terrain and natural hazards, and schedules; and (3) field trip code of conduct for students and instructors. The detailed documents aided an international volcanology field trip to New Zealand, facilitated complicated travel logistics, and emphasized effective place-based science with cultural significance included with each geology stop. For an undergraduate-focused field volcanology course in Oregon, the pre-field trip survey allowed students to share their concerns and questions before the trip, enabling the instructor and teaching assistants to better serve the students who had not been in the field before, ultimately enhancing overall learning outcomes. While these steps required some new field trip planning, department-wide adoption of these standards and templates has eased the overall effort and made field learning more accessible.

Theme: 7. Communication in Volcanology

Session 7.3: Advancing equity and diversity for a more inclusive future in volcanology

Allocated presentation: Poster

Risk Faults. Relocation, Displacement and Homemaking on the Slopes of Mount Etna (Italy).

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Between 2023 and 2024, the Department of Political and Social Sciences at the University of Catania, in collaboration with the National Institute of Geophysics and Volcanology (INGV) and the Commissioner's Office for the Reconstruction of the Etna Area (SCRAE), launched an experimental project on disaster anthropology. This research focused on the relocation processes affecting households in nine municipalities on the eastern slope of Mount Etna, impacted by the severe seismic event of December 26, 2018 induced by the sudden intrusion of two dikes close to the SE crater of Mount Etna (Mattia et al. 2020). SCRAE adopted a selective relocation strategy, moving only families whose homes and productive activities were located near the fault line, marking a notable departure from traditional post-seismic reconstruction strategies in Italy. The project explored the experiences of forced displacement and the evolving dynamics of homemaking that followed. Key findings included the role of economic incentives in fostering acceptance of institutional decisions, the positive impact of negotiation mechanisms employed by the reconstruction agency, and the gradual reshaping of local perceptions about living in an area frequently exposed to moderate, yet potentially devastating, seismic events related to volcanic activity.

Theme: 7. Communication in Volcanology

Session 7.3: Advancing equity and diversity for a more inclusive future in volcanology

Allocated presentation: Poster

Navigating different worlds on volcanoes in Latin America: Results from the IMAGINE project

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This poster will discuss results from the IMAGINE project, which has examined scientific and societal understandings of volcanoes in parts of Latin America. Working with communities, museums and volcano observatories, the project sought to understand the different kinds of knowledge and experiences of people living on volcanoes, recognising that "risk" as an idea may be imposed from the outside. The geohistory of these communities is a significant part of their identity in a range of different ways, but they do not necessarily view volcanoes as a "risk" at all. Communities include indigenous groups as well as settlers and more recent arrivals linked to new industries including geotourism and geoparks. The project sought to be collaborative and equitable in its approach, allowing communities and collaborators to define the most important goals and outcomes.

Theme: 7. Communication in Volcanology

Session 7.3: Advancing equity and diversity for a more inclusive future in volcanology

Allocated presentation: Poster

How far is the next volcano? The spatial distribution of volcanologists

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Volcanoes are not randomly located on Earth; neither are volcanologists. We computed the physical distance between volcanologists' affiliations and volcanoes by considering two categories of volcanoes: (1) volcanoes that erupted in the Holocene, and (2) in 1974–2024. Affiliations were extracted from articles published since 1980 in four of the main English speaking volcanology-focused journals. 27% of volcanologists are based within 100km of a Holocene volcano (world population: 14%). >85% of volcanologists are within 1000km of a Holocene volcano, but 48% must travel >1000km to visit a volcano that erupted in the past 50 years. We observed that researchers working nearer volcanoes tend to lead articles with more co-authors. We also found that authors in further positions tend to be based nearer recently active volcanoes, though this correlation is less significant. Using keywords to identify each article's studied volcano, we performed single volcano analysis. We observed significant differences in the distance from authors to the target volcano. For instance, we obtained median author-volcano distances of 9 km for Campi Flegrei and 11,735 km for Merapi. This analysis also permitted a simplistic estimate of the carbon footprint from fieldwork travels, yielding CO_2 equivalent emissions in the range 0.3-2.6 ton/article. The database presented is very rich and could serve future efforts in science strategy, equality, diversity and inclusivity, outreach, and sustainability. This poster will present the main outcomes from this study, focusing on the volcanoes that erupted in the last 50 years, bibliometric implications for equality, diversity and inclusivity and outreach potential.

Theme: 7. Communication in Volcanology

Session 7.3: Advancing equity and diversity for a more inclusive future in volcanology

Allocated presentation: Poster

Closing the Digital Accessibility Gap: Digital Inclusion in Volcano Observatory Websites

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A recent World Health Organization study highlights that one in six people worldwide lives with a disability or special need. Today, most information is shared through public websites, making it available from nearly anywhere. However, to ensure that this information is usable and understandable for everyone regardless of personal conditions such as disabilities or age-related challenges, it must be presented in an accessible format. In this context, digital accessibility (DA) has become a standard approach in information technology, involving the adaptation of content formats to accommodate diverse needs. Ensuring DA is especially critical for governmental agencies responsible for monitoring natural phenomena that can lead to natural disasters, including volcanic eruptions and earthquakes. In this study, we examine the DA of websites from various volcano observatories that provide critical information, including near-real time updates, on volcanic activity and state of unrest during crises. After analyzing different websites layout and structure, non-textual elements, tables, and other important elements, our analysis reveals that the design or content format of these websites hinders interaction for users of assistive technologies, such as screen readers (primarily used by blind individuals) and keyboard navigation (used by people unable to use a mouse), among other aspects outlined in DA guidelines and principles. These barriers create difficulties to understand the information related to natural disasters. We hope our analysis will guide governmental agencies and organizations in effectively communicating important information to everyone, including people with special needs, thereby improving preparedness and response efforts for volcanic eruptions.

Theme: 7. Communication in Volcanology

Session 7.3: Advancing equity and diversity for a more inclusive future in volcanology

Allocated presentation: Poster

The Canary Project: An inclusive course-based undergraduate research experience in mineralogy, petrology, and volcanology

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Participation in authentic scientific research positively impacts undergraduate student learning and retention in the sciences, particularly among underrepresented groups, making it a highly recommended teaching strategy. Course-based undergraduate research experiences (CUREs) are more inclusive than independent research experiences, but not all types of research are amenable to such teaching activities. Here we present the design and initial outcomes of the Canary Project, a CURE in a core mineralogy and petrology course at Queens College, City University of New York. The project addresses the research question “What magmatic processes, as recorded by zoning patterns in crystals, lead to renewed eruption at quiescent hotspot volcanoes?” based on the simplicity and power of backscattered electron images acquired on a scanning electron microscope (SEM). Students work in pairs, each assigned a specific historical eruption in the Canary Islands and corresponding thin section and tephra sample. Students participate in research hypothesis design, sample preparation, SEM data collection, data analysis, and dissemination in a poster symposium. A tiered mentoring system involving faculty, graduate students, and experienced undergraduates supports participants throughout the project. A post-pre survey measures student learning outcomes. To date, a diverse pool of 23 students have engaged in the Canary Project, demonstrating improvements in both general scientific and mineralogy-petrology-specific skills. Survey data also indicate enhanced engagement due to the authentic research experience. The Canary Project exemplifies how CUREs can integrate accessible research tools to promote scientific inquiry and build essential skills, fostering inclusivity and deeper engagement in the geosciences.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Talk [Invited]

Sensing Volcanoes: improving understanding of eruptions through 'hands-on' experiences

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The spectacle and wonder of volcanic activity are an easy draw for exciting curiosity towards outreach and engagement activities but creating lasting understandings of the processes that drive different types of activity and their consequences for communities at risk is more challenging. This series of demonstrations shares how we have accessed audiences sense of hearing, smell and touch (as well as sight) to recreate and share important dimensions of changing volcanic behaviour through 'Mountainaglow' and 'SoufriereBlow' in the Eastern Caribbean and 'Sensing Volcanoes' in the UK. To help imagine the difficult choices and sometimes life-changing impacts of eruptions we also share the elements and challenges of a 'serious game' we play with a wide variety of audiences. We have evidence this approach is engaging, and that it provokes more nuanced understandings of eruptions and their impacts, and stronger empathy with affected populations. However, the act of imagining risk and uncertainty can also provoke stronger (negative) emotional responses to volcanic activity than wonder or curiosity. This can be counterproductive, so we also celebrate the value and strength of positive social and cultural responses to past eruptive events. We will share the evidence we have for both the value and challenges of working in this way, and the further potential for using arts-based or interdisciplinary approaches to engagement. Not only in making knowledge of volcanic activity accessible but to support improved social responses to future eruptions.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Talk

Using the Twitch interactive live-streaming platform as a tool to communicate and educate about volcanoes and volcanic hazards.

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Active volcanoes are often viewed on social media as fun places to spend vacations and as a means to gain more followers by posting dramatic photos and videos. Commercial travel agencies also use social media to convince people to travel to an active volcano for spectacular vacations. Social media can also be useful educational tool to communicate about active volcanoes and volcanic hazards. However, creating interactive content is challenging, as is successfully reaching an audience not already looking for volcano-related content. Twitch's interactive live-streaming service has more than 240 million unique visitors monthly and offers free live-stream services with a live chat. Since the Fall of 2021, L'Hebdo Des Volcans has provided a weekly stream about active volcanoes with the aim of 1) educating about volcanic hazards, 2) explaining eruption processes, and 3) answering viewers' questions. Doing so, viewers gain a better understanding of how to behave and remain safe when traveling to active volcanoes and learn where to find reliable information (e.g., from officials, observatory institutions). A wide range of content is used to make the streaming visually appealing, including photos, videos, social media content, and media articles. This is complemented by scientific articles from volcano observatories, open-access journals, and volcanologist guests to talk about specific topics. Twitch's interactive live-streaming service is one venue where volcanologists can actively contribute to building trust in science, engage with viewers, and develop new ways to communicate about volcanoes and volcanic hazards

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Talk

Understanding volcanoes through the eyes of students: The new GVP/USGS Student Volcano Art Gallery

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The Smithsonian Institution's Global Volcanism Program (GVP) in partnership with the United States Geological Survey (USGS) launched a new outreach project in August 2024 called the "Student Volcano Art Gallery". This project aims to raise volcano awareness among younger students and promote interest and curiosity about volcanoes, show the intersection of the arts and sciences, and encourage students to learn more using the GVP website. Students across the United States between the ages of 5-18 were encouraged to submit an original art piece using any medium (except video) that depicted a volcano or a volcanic eruption within the theme of "Volcanoes Around the World". The call for submissions was made on 15 August 2024 and was promoted through personal communications and broadly advertised on various platforms, including on social media (X and Facebook), the Volcano Listserv at Arizona State University, and Smithsonian online newsletters. The timing of this project was considered based on the beginning of the academic year for most US schools. Students submitted pieces depicting lava flows, subduction, and ash plumes, sometimes including themselves and family members. A select number of pieces were published on the GVP website in a Photo Gallery devoted to the students' art, with submissions divided into four age-group categories. This program will continue in future years, and we hope to expand the participation to international students.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Talk

Getting to know Aotearoa-New Zealand's nearshore volcanoes – A user-centred design approach to science translation products

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Aotearoa-New Zealand's nearshore volcanic islands pose a threat to our communities with the potential for impacting more than 1.5 million individuals, as well as our economy, through both volcanic and non-volcanic hazards including ash fall, pyroclastic flows and tsunami. The Beneath the Waves research program aims to improve our understanding of the island volcanoes of Whakaari and Tūhua. We take a multi-disciplinary approach to exploring the anatomy of the volcanoes, simulating the physical processes and potential impact, determining potential consequences for communities and examining how to integrate results into forecasts, alerts and preparedness. To ensure the maximum uptake of the science, the program is linked with diverse end-users creating pathways for relevance, including Indigenous Māori, councils, emergency management partners and industry users, as well as existing research outreach agencies. Engaging with our science-impact partners, for example Civil Defence Emergency Management agencies in regions with potential impacts from Whakaari and Tūhua, provides an opportunity to tailor information about these volcanoes into products that are useful and usable, increasing the feasibility that they can be used to support science-informed decision-making at all levels. We utilise several user-centred design methods including the collaborative approach of participatory design and will share our current progress on some key products. By involving the users in the design process we seek to create user-centric communication products, including dynamic digital products (e.g. ArcGIS StoryMaps) and approachable science fact sheets, that are designed with purpose, are engaging, clear and promote the connection of communities with the natural environment.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Talk

The Volkis' adventure: the perfect combination of science and creative illustration

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Earth Sciences often receive less attention than other basic sciences, particularly among teenagers. This issue is more pronounced in countries where primary and especially secondary education systems prioritize other science subjects over Earth Sciences. Early childhood interests shape future curiosity, and fostering enthusiasm for understanding our planet and environment during formative years is critical. To address this, developing engaging educational tools has become a pressing challenge. Comics, graphic novels, and illustrated books are increasingly effective in introducing scientific concepts to children and teens. One such resource is "**The Volkis: A Volcanic Adventure**", a creative tool designed to teach young audiences about volcanoes, their workings, and their societal impacts and benefits. The story follows the Volkis, a secret club of volcano enthusiasts, led by Rocky, the group's experienced mentor. Through their adventures, readers explore key aspects of volcanology. The book is filled with engaging sections and characters representing volcanic products, guiding readers and educators through an exciting journey into volcanology. It is available for free and supported by a website (https://descubrelosvolcanes.es) offering additional materials like videos, experiments, and coloring pages. The ultimate goal is to make science education entertaining, accessible, and interactive, fostering learning not only for children but also for the adults accompanying them, breaking traditional paradigms of teaching science. This geo-educational tool offers even greater potential by expanding to new adventures exploring the volcanic heritage of regions like the Canary Islands—highlighting La Palma and the 2021 Tajogaite eruption—and the Catalan Volcanic Zone.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Talk

Will my house resist to volcanic hazards? Let's be prepared!

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Built awareness to volcanic eruptions is fundamental to understand volcanic consequences and ultimately reduce future risk. Due to the multiple nature of volcanic products, a large variety of impacts are associated with eruptions. We set up an environment with houses, people, cars and various assets exposed to lava flows, ballistics and tephra fallout. We will discuss the damage caused by these products and how the communities living around volcanoes can be better prepared to face these impacts. For lava flows we will use a slope with different viscosity fluids to show the importance of magma properties on the time of evacuation and self-protection. For tephra fallout we set up an inhabited area made of carboard houses with different built typologies. We explore then the resistance of these houses to the load due to tephra accumulation and impacts of ballistics. With this activity we introduce the concepts of i) hazard parameters ii) exposure of elements to volcanic hazards, ii) physical vulnerability of houses; and iv) the role of community preparedness in reducing impacts. This activity can be used by teachers and stakeholders located in volcanic settings to raise awareness in the residents but also in the people susceptible to travel to volcanic areas.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Poster

MULTI-MAREX: A living lab for improved forecasting and possible actions for multiple extreme geomarine events

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Extreme geomarine events, including volcanogenic or seismogenic tsunamis and earthquakes, as well as their cascading events, have serious short- and long-term consequences for coastal communities. Early warning and disaster prevention are both societal and political challenges that the MULTI-MAREX collaborative project, part of the 'Marine Extreme Events and Natural Hazards' research mission of the German Marine Research Alliance (DAM), will address by creating a living laboratory. This living laboratory will provide opportunities to study extreme geological events and associated hazards in order to develop the knowledge needed to manage these hazards at different levels in Greece. Enormous changes in the natural environment due to interaction and modification by human activities over the last 250 years have led to increased vulnerability of the infrastructure, economy and surrounding population. The overall objective is not only to characterise geological processes, but also to develo and to ensure more effective early warning systems, and to develop protective measures in close co-design with researchers from different disciplines, working closely with the authorities and the local population, so that everyone in or around coastal communities are effectively informed and protected from extreme events. Through our research and our commitment to knowledge and technology transfer, we make a significant contribution to preserving the function and protection of the ocean for future generations. GEOMAR is responsible for the communication and coordination between the partner institutions of the joint project, the stakeholders and the DAM, as well as with the funding organisations.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Poster

Digital Tools in Volcanic Regions: The Power of INVOLCAN's Social Media

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Scientific communication should be one of the core pillars of any research institution. For this reason, at the Instituto Volcanológico de Canarias (INVOLCAN), we strive to establish effective communication with society through tools such as social media, in an accessible, direct, and, above all, educational manner. Today, social media is an integral part of a digital, organic, and dynamic ecosystem, where people actively participate in generating and sharing information. Aware of this, we make a continuous effort in public outreach and education to raise awareness among the population living in a volcanically active region, such as the Canary Islands. INVOLCAN's communication strategy is implemented across three platforms: Facebook, Instagram, and Twitter/X. This enables us to create a variety of posts that allow us to reach a broader segment of the public. Through these platforms, INVOLCAN promotes knowledge about volcanic processes, shares updates on volcanic activity in the Canary Islands, and highlights the importance of proper volcanic risk management for the future. We also emphasize the benefits of living with volcanism, such as the geotourism and geothermal development. Volcanology is an increasingly relevant topic in the communities living on active volcanoes. During volcanic crises, social media becomes essential, as it allows for the rapid and active dissemination of verified information, reducing misinformation and fake news while strengthening the resilience of local communities. In an increasingly digital world, social media stands as an indispensable pillar in enhancing outreach and education on volcanoes and it is clear a clear challenge for INVOLCAN.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Poster

Journalists, Communication and Volcanic Risk Management in Canary Islands, Spain

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Effective volcanic risk management requires the coordinated efforts of scientists, authorities, journalists, sociologists, psychologists, and other stakeholders. Within this framework, communication professionals play a critical role in translating complex scientific information into accessible messages, informing the public about volcanic hazards and fostering preparedness. To fulfill these responsibilities, they require not only a solid understanding of volcanoes and risk management strategies but also the ability to critically evaluate these strategies to ensure transparency, accountability, and public trust. This research aims to assess the level of understanding and interest that media professionals have about volcanoes and volcanic risk management in Spain, and to examine the potential and desired role of the media in enhancing the effectiveness of volcanic risk management efforts. To evaluate the knowledge, attitudes, and practices of journalists concerning volcanoes, volcanic risk management, and communication in Spain, we developed an online questionnaire. The questionnaire consists of approximately 25 questions and can be completed in about 15 minutes. Approximately 24% of the questionnaire consists of general questions including residence, gender, age and education level. Questions and comments related to volcanoes and volcanic risk management make up approximately 42% of the questionnaire, while the remaining 32% focus on communication and the role of the media in volcanic risk management in Spain. The questionnaire was released on December 26 2022 and by the end of the year 2022, a total of 105 journalists had completed it. Here, we present preliminary results, including qualitative data on the needs and perception related to volcanic risk.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Poster

Tourists' perception of volcanic hazards and risk in Tenerife, Canary Islands

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The Canary Islands constitute a volcanically active region where volcanic risk has significantly increased over the past 50 years due to higher population densities and growing socio-economic exposure to volcanic hazards. Understanding the perception of volcanic hazards and risks among societal groups - such as communication professionals, tourists, urban planners, and the general public - is essential for effective volcanic risk reduction strategies. While some groups have specific roles, tourists represent a significant floating population that can contribute to risk management. Annually, the Canary Islands attract 8 to 13 million visitors (National Statistics Institute - INE), highlighting the need to integrate tourists into risk strategies. This study explores Tenerife's tourist awareness, understanding, and interest in volcanoes and volcanic risk management in the Canary Islands. It also examines their potential and preferred roles in enhancing the effectiveness of volcanic risk reduction efforts. To achieve these objectives, we designed a face-to-face questionnaire comprising approximately 30 questions, completed in 10 - 15 minutes. About 20% of the questions focus on demographic information, 40% address knowledge of volcanic phenomena and risk management, and the remaining 40% assess tourists' perceptions of volcanic hazards and risks. The survey was conducted in two phases: between July and September 2023 (419 respondents) and in September 2024 (323 respondents), resulting in a total sample of 742 tourists. The findings of this research will contribute to tailoring communication strategies and risk reduction measures, ensuring that tourists are informed and empowered to actively manage volcanic risks on Tenerife Island and beyond.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Poster

The Volcano of Nisyros Digital Twinning

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Nisyros, a small Greek island in the southeastern Aegean Sea, is home to Greece's youngest active volcano, featuring a 3.8 km-wide caldera. The island's geological history spans 160,000 years, with its youngest formations dating back 15,000 years. A digital twinning project aims to revolutionize tourism and education by creating a virtual replica of the volcano, offering a real-time and immersive experience. The initiative involves developing a 3D digital twin of the crater using photogrammetry to create a detailed and realistic model. Integrated with real-time sensor data, it will provide dynamic updates on conditions like temperature and gas emissions. Visitors can explore the volcano virtually, access historical and live data, and view 360-degree images. This interactive platform promotes sustainable tourism and education by offering tailored experiences for tourists, students, and educators. The project highlights environmental impact and resilience while leveraging artificial intelligence and emerging digital environments to enhance realism. A comprehensive web platform will combine a 2D crater map with the 3D model. Icons on the map will provide access to detailed sensor data, fostering a deeper understanding of the volcano's dynamics. The backend of the application will manage the digital twin and communicate with the frontend through RESTful APIs. This innovative approach not only enriches tourism but also emphasizes environmental awareness and sustainable practices, providing a cutting-edge digital exploration of Nisyros' volcanic heritage

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

Unveiling Kolumbo: Exploring Submarine Volcanoes and Their Hazards

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Dive into the captivating depths of the Aegean Sea with this engaging 20-minute science demonstration, designed to unveil the hidden world of underwater volcanism. Through the WAVES project, we present a customized 3D model of Kolumbo, one of the most active submarine volcanoes in the Christina-Santorini-Kolumbo volcanic field. The model is about 1.2m long and can be taken apart to show the seismic structure beneath the surface. This allows an interactive interpretation of the eruption history. Located in the Aegean Sea, the Christina-Santorini-Kolumbo volcanic field has explosively erupted over 100 times in the past 650,000 years. Kolumbo was chosen for this demonstration not only because of its geohazard potential but also due to its proximity to Santorini, a globally renowned tourist destination visited by over 2 million people annually. Understanding and monitoring Kolumbo are critical to mitigating risks to coastal communities and visitors alike. This demonstration showcases methods of marine geosciences that scientists use to investigate beneath the sea, including multibeam imaging and geophysical monitoring techniques and bridging that to societal issues. Participants will gain insight into the risks posed by submarine volcanoes and how research improves prevention and preparedness. The public will explore the fascinating interplay between volcanology and the marine environment, fostering curiosity and critical thinking about natural hazards beneath the waves. **Practical Details**: - **Languages Offered**: English, French, German, Spanish - **Duration**: ~20 minute - **Materials Needed**: Large table, screen, poster frame

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

How our phones are connected to volcanoes? Come and see how the largest copper treasures of the Earth form!

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Volcanoes are intertwined with human life since prehistoric times. Whereas on one hand they may be source of destruction, on the other they provide elements that are essential to humans, like potassium and magnesium which are fertilizers of soils for agricultural crops. Perhaps less known, volcanoes are also, in some rare cases, intimately associated with the major sources of copper on Earth. Copper has been one of the most important metals for human civilization and, nowadays, is essential for the transition to a green economy. It is estimated that its demand will overcome known natural resources within a few years, which is fostering efforts to find new copper resources. The largest natural copper resources are the so-called porphyry copper deposits. Most of these deposits form 1-6 km under volcanoes associated with subduction zones, like those of the Andean Cordillera in South America. The magma reservoir under volcanoes may feed explosive eruptions through the catastrophic liberation of fluids inside the magma ascending towards the surface, but may also release fluids in a quieter way. Such fluids consist principally of water, some chlorine and sulfur and trace amounts of copper and other metals. Copper is precipitated as copper-rich sulfide minerals, like chalcopyrite ($CuFeS_2$), due to cooling of the fluids released by the magma reservoir when they ascend towards the surface. Here we will present a model of how porphyry copper deposits form, also showing samples of rocks and minerals, and how they relate to the life of a volcanos.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

Be an expert on volcanic degassing

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A quiz table game on volcanic degassing is set up with four levels of questions to be completed to obtain a certificate of expertise. Players roll a dice and answer questions related with four main topics: type and composition of volcanic gas emissions, sampling equipment and analytical techniques, data interpretation, and gas hazards. Different levels of difficulty are set, and players answer questions progressively until they reach the final level, which is rewarded with a certificate. Some questions are illustrated with pictures and are based on study cases from around the world. If questions are answered correctly, the player can roll the dice again; differently, the player incurs a penalty defined by a set of additional cards, which may include returning to the previous level. A digital certificate is awarded to those who successfully complete the final level. The game is in English, but can be easily adapted to Portuguese and Italian. There is no limit to the number of players, but a maximum of four players per game is recommended. Material needed: We will need a table and a computer.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

From appearance to processes: What volcanic rock textures tell us about their formation

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In this activity, a collection of various volcanic rocks is exhibited to the public. During the first part, people are given a few minutes to look at the rocks, and also to manipulate them (to see how light or heavy they are, for example). They are instructed to take notes – mental or paper – about each rock's texture: its shape, color, and density; the presence or absence of crystals or vesicles; etc. During the second part, the public is asked to guess which processes may have given its appearance to each rock. A small slideshow (one slide per rock) is presented with the solution. The collection contains a dozen different rocks, with very different looks and formation histories: a fusiform bomb; a bread-crust bomb; bombs with enclaves of peridotite or basement rock; various types of obsidian and pumices; a section of pillow lava… coming from a variety of volcanoes in France, Iceland, Italy, Indonesia. Formation histories include: What does the shape of a fusiform bomb tell us about its cooling trajectory?; How rocks that formed at the bottom of the ocean can be found today at an elevation of 3,000 m above sea level?; and many more. This demonstration has been done on multiple occasions with children from primary and secondary schools, but is suitable for all ages. It requires a table to exhibit the rocks, and a projector to present the slideshow. It can be given in French or English.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

Are you sure it's a volcano?

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Volcanic activity has many facets and although we all have a predefined image of how a volcano looks like, Earth and other planets in our Solar system feature unexpected and special volcanic structures. Our outreach activity will engage the public in seeing beyond what they know about volcanic features. We will use a series of images such as pancake structures on Venus, black smokers on Earth, colorful lava flows from Io… to illustrate the beauty and variety of volcanic activity in our solar system. We aim to spark interest, reflection, and trigger questions and discussions about how one entity- a volcano- can have so many natural expressions. We will then ask participants to draw on a large fresco their vision of an extra-terrestrial volcano. The fresco will be put on display the last day of the conference.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

Should I Flow or Should I Blow? That's Important to Know!

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Volcanic eruptions can manifest in markedly different styles, ranging from effusive outpourings of lava to highly explosive events that produce ash clouds and pyroclastic materials. This contrast arises primarily from the interplay between magma viscosity and magmatic gas supply. Understanding such processes is crucial, not only for volcanologists but also for communities living near active volcanoes who rely on effective preparedness strategies. Science communication and demonstrations play a fundamental role in this process. To engage broad audiences, we propose two hands-on demonstrations showcasing the fundamental physical principles governing effusive versus explosive eruptions. These demonstrations are regularly performed by the *Enviroscope* program of the University of Geneva. First, a "lava flow" experiment uses materials of varying viscosities poured down a slope to illustrate how viscosity affects flow velocity and morphology—a key factor driving effusive eruptions. Second, a "Cola and Mentos" experiment models the role of dissolved gases in explosive eruptions by demonstrating how rapid gas expansion propels volcanic fragments into the atmosphere. These accessible, visually striking demonstrations are powerful tools to communicate complex volcanic concepts, bridging the gap between scientific research and the public. By highlighting the critical influence of magma rheology and gas content, our approach aims to foster a deeper appreciation of volcanic hazards and stimulate greater community engagement in hazard mitigation and preparedness. Language of activity: French (English if needed). Materials: metallic slope; various viscosity liquids (i.e., teeth paste, hair gel, soap, ketchup); Coke and Mentos; Rock samples; one table.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

Discovering Iceland's Volcanoes: An Educational Approach to Science Communication

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The Iceland Didactical Project 2024 is an educational initiative led by second-year Bachelor students in Earth and Environmental Science from the University of Geneva, supported by their professors, research group members and SciencEscape, a non-profit science outreach organization. To reduce our CO_2 footprint of about 40%, we travelled by car and ferry, from Geneva to Reykjavik following the results of an impact study we performed. Once on-site, we met Þorvaldur Þórðarson, volcanologist, and Halldór Geirsson, geophysicist, from University of Iceland, who gave lectures on their field of study on the Reykjanes Peninsula and strengthened links between our mutual universities. Þorsteinn Sæmundsson, landslide specialist, led a fieldtrip to observe the results of the largest landslide recorded in Iceland in historical time. The tipping point of our project was the visit to the Icelandic Meteorological Office. Michelle Parks presented the volcanic events of Sundhnúkurgigar and offered a new perspective on volcanic eruptions and its impact on residents. Another crucial aim of the project is the production of a documentary about the project produced by SciencEscape, screening at UNIGE and at the Scientific Assembly of IAVCEI 2025 in Geneva, strengthening links between academic institutions and the public. Drone and camera footages were taken throughout the whole project, from the departure in Geneva to the ferry route, fieldwork, data collection in the laboratory and data discussion during the courses. By managing all phases of this research project—scientific, logistical, and financial—we gained practical skills and critical insights for academic and professional growth.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

The shapes of volcanoes

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Volcanoes come in different sizes, shapes, and types. Each of them tells a different story of construction and destruction, of erosion and time. Unravelling these stories is the main focus of an interdisciplinary research area called volcanic geomorphology, which, with the help of satellite images, digital elevation models, fieldwork, analogue experiments, and computer simulations, aims to contribute to understanding the nature of volcanic phenomena. In this interactive workshop, we will explore the diversity of volcano shapes, some of the processes we can infer from them and some questions still waiting to be answered. Duration: 1 hour. Language: English. Requirements: screen or projector, tables.

Theme: 7. Communication in Volcanology

Session 7.4: Enhancing volcanoes understanding: science demonstrations to communicate knowledge with the public

Allocated presentation: Demonstration

Echoes of Eruptions: Humanity's Story in the Shadow of Volcanoes

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Human history is deeply entwined with volcanic activity, with eruptions a powerful force in shaping our modern societies. Volcanic eruptions can cause global chaos through their interactions with human systems and through their influence on global climate. Indeed, eruptions have been linked to the rise and fall of civilisations, including the Chinese dynasties over the past 2000 years, the Sasanian Empire and the Eastern Türk Empire. They drive migrations of population and have even influenced the drawing of land borders. Human societies have long focused their development in the shadow of volcanoes, which provide rich and fertile lands to support their populations and for this reason, today, some 10% of the global population, now live in proximity to active volcanic regions. But despite the benefits they provide, volcanic eruptions pose a considerable risk to our global societies, that remains poorly understood and woefully neglected. In our highly immersive and visual exhibit, designed by professional artists, we will share the stories of how disruptive volcanic eruptions throughout history have shaped human societies and explain how learning from the past helps us to prepare for the risks we face in the future. Using data sculptures, narratives and games, we will take participants on a journey through time, explaining how volcanoes can affect our modern world, and share ideas about what we should be doing to increase our resilience to future eruptions, and how a new charity in this space, the Global Volcano Risk Alliance, aims to do this.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Talk [Invited]

Breaking Silos: Collaborative Pathways in Volcanological Technology Development

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Despite rapid advancement of powerful tools and methodologies, from machine learning algorithms to sophisticated process modeling and real-time sensor networks, the landscape of technology development in volcanology is often fragmented. Individual researchers and institutions work in silos and peer review systems and competitive pressure keep scientists from sharing data in a timely way. Redundant efforts and slow integration of innovative solutions into broader volcanological practice are the norm. Drawing on examples of successful interdisciplinary initiatives and crowd sourcing concepts we can showcase how collective innovation in database design, open-source software development, and machine learning applications could accelerate problem-solving and enrich the scientific ecosystem. There are practical frameworks for fostering collaboration among technology developers in volcanology including establishing centralized repositories for shared code and shared data, creating virtual forums for ongoing dialogue, and setting cross-disciplinary goals to stimulate creative solutions to shared challenges. We must rethink the way we develop and share data. By embracing collaboration, we can avoid duplication, maximize efficiency, collect more data faster, and speed technological advancements for the benefit of the volcanology community and beyond. Call for action: Pictures (with location embedded) of eruptions, especially lava fountains, geysers, and ash plumes are needed now to complete the development of an application that automates estimating the height, width and bubble formation of active events.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Talk [Invited]

Integrating Standardized Volcano Monitoring Data into WOVOdat

Christina Widiwijayanti*[1], Benoit Taisne[1,2], Fidel Costa[3], Nang T.Z. Win[1], Tania Espinosa-Ortega[1], Christopher G. Newhall[4], Antonius Ratdomopurbo[5], and WOVO observatories

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Volcano monitoring data are essential for understanding volcanic processes, improving eruption forecasts, and mitigating risks. However, the lack of standardized formats and open-access platforms hampers data sharing and collaboration, with many unrest episodes archived in diverse formats, often without metadata. WOVOdat (World Organization of Volcano Observatories Database), hosted by the Earth Observatory of Singapore, addresses these issues by curating global volcanic unrest data into a centralized, standardized, and open-access database. It integrates seismic, deformation, gas, thermal, and other monitoring data, accessible via a web-based platform (***wovodat.org***) for querying, visualization, and download. Complementing this is the Global Volcano Monitoring Infrastructure Database (GVMID), which compiles metadata on monitoring networks, stations, and instruments, enabling global analyses of monitoring capabilities and identifying gaps. These resources facilitate efficient use of datasets to tackle global challenges, such as improving eruption forecasts through statistical analysis of precursory signals, pattern recognition, and unrest comparisons. They support the development of probabilistic eruption models and enhance decision-making during crises. As part of an IAVCEI initiative, the Bulletin of Volcanology has introduced *Data Reports*, a format for publishing monitoring data with DOI assignment and copyright protection. These datasets can be then archived in WOVOdat, enriching its repository. These efforts underscore the transformative potential of open science in volcanology by promoting transparency, collaboration, and innovation. We encourage the global volcano community to contribute to and utilize WOVOdat and GVMID to advance research, forecasting, and crisis management worldwide.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Talk [Invited]

The Volcanology Infrastructure for Computational Tools and Resources (VICTOR)

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The volcanology community has been expressing, through National Academies reports, workshops, and research coordination networks, a need for centralized and modern cyberinfrastructure and computational tools. As the community prepares for future volcanic eruptions and their potential global impacts, the availability and accessibility of reliable and sophisticated models is particularly important. The Volcanology Infrastructure for Computational Tools and Resources, VICTOR, answers this need. VICTOR provides the volcanology community with open-access, open-source computational tools for modeling volcanic processes in a low-cost, accessible cloud-based environment. VICTOR is accessed through a central web portal that includes links to thorough documentation and user-focused communication channels. The cloud-based architecture allows for demand-based resource management and workflow portability and reproducibility. VICTOR already includes a library of eruption simulation codes, mathematical and data science tools, a sandbox for the development and execution of workflows, and interfaces to external resources such as remote sensing and topography datasets. Next, VICTOR will expand its core mission of a transparent and efficient integration of community codes, ensuring that the wider community has easy access to cutting-edge software at a low cost. The existing and newly added individual components will then be harnessed towards more advanced workflows, such as for inversion of observational data and uncertainty quantification. Lastly, to sustain and grow VICTOR as an effective community-focused cyberinfrastructure, we propose a comprehensive, multilayered plan for communication with the volcanology community, from webinars and recorded tutorials (in both English and Spanish) about computational geophysics and the tools available, to short courses, hackathons and workshops.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Talk [Invited]

Breaking barriers in science: Insights from Latin America's Volcano Observatories dual-language Special Issue

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Peer-reviewed articles in international journals remain the foundation of sharing scientific knowledge across the globe. However, these publications are typically written exclusively in English and often come with financial barriers—either requiring fees from readers or charging authors for open access. In the field of volcanology, Volcanica stands out as the only fully diamond open-access journal, offering peer-reviewed articles at no cost to either authors or readers. This young scientific journal is committed to tackling some of the most significant obstacles in research publication while enhancing the accessibility of published research outputs. In collaboration with the *Asociación Latinoamericana de Volcanología* (ALVO), Volcanica presents a Special Issue on the critical work conducted by volcano observatories across Latin America—a region where tens of millions of people live under the threat of volcanic activity. Published as Reports, a flagship format tailored for this kind of institutions, the publications are authored by representatives, managers, scientists, and researchers from observatories in the ten Latin American countries currently operating official volcano monitoring programs. To break down language barriers, each article is available in both English and Spanish. While publishing a dual-language issue adds significant workload for authors, editorial board, and technical teams, it represents meaningful step towards inclusivity. Emerging technologies, such as AI-powered translation tools, could play a pivotal role in simplifying the process of publishing in multiple languages. By bridging linguistic divisions, this effort aims to make research in volcanology and observatory actions accessible to a broader audience, encouraging greater inclusivity and collaboration.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Talk

Development of Volcanic Hazards Information System in Geological Survey of Japan

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The Volcanic Hazards Information System is developed for (1) real-time hazard assessment using online numerical simulations, (2) eruption parameter analysis at various volcanoes, (3) digitization of tephra fall, PDC, and debris avalanche distributions, (4) online tephra fall volume estimation, and (5) display volcanic crater distributions. The Volcanic Hazards Information System allows it to execute Energy Cone, Titan2D, and Tephra 2 numerical simulations on Quaternary volcanoes worldwide using ASTER GDEM and GSI 10 m DEM. Therefore, quasi-real-time volcanic hazard assessment is possible using a more rapid display and comparison with previous eruption cases. The examples of eruption parameters are essential for numerical simulations even after eruption initiation to determine the appropriate parameters, hazards and risk assessment, and future prediction of eruption scenarios. Currently, 313 cases, in total, are analyzed on the system (as of Dec. 2024). The API function using WMS (web mapping service) provides all simulation results and allows them to be displayed on various servers, GIS software (e.g., QGIS), and Google Maps. The online tephra fall volume estimation system (WebTephraCalc) was developed using segment integration, exponential, power law, and Weibull methods. The areas of each contour are calculated, and the volume of each segment is estimated on the system. Volcanic Hazards Information System is expected to be used by many stakeholders, such as researchers, students, consultants, local government staff, and Geopark staff members for geological hazard assessments, revision of disaster prevention maps, and education purposes.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Talk

FAIR access to geoscientific data from Iceland on the EPOS Data Portal

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The dynamic environment of Iceland provides a wealth of diverse geoscientific data. In addition to lively earthquake activity and plate spreading, volcanic eruptions occur every 3-5 years on average, often in a glaciogenic environment. By definition, volcanological data is very heterogeneous and close collaboration between different geoscientific fields is therefore vital. The Icelandic Volcano Observatory is hosted at the Icelandic Meteorological Office (IMO), which is responsible for monitoring all natural hazards in Iceland and required to archive and conserve diverse, digitally acquired data that are constantly being collected. The key to understanding and forecasting future natural hazards in Iceland requires stringent checking to ensure research quality of these monitoring data. In order to enhance future developments of knowledge, IMO joined the ranks with EPOS (the European Plate Observing System) in 2010, taking the first step towards making geoscientific data FAIR. An important milestone for Icelandic participation in EPOS was achieved in 2021 through the national infrastructure project EPOS Iceland (epos-iceland.is), a joint effort of IMO, University of Iceland, Natural Science Institute of Iceland and ISOR-Iceland GeoSurvey. EPOS Iceland is one of six infrastructure projects on the first Icelandic national Research Infrastructure roadmap. The project has enabled FAIR access to data through 18 API services on the EPOS Data Portal and strives to (i) quality check and standardize more geophysical and geological data, (ii) provide FAIR data in open access and (iii) maintain and build more services with long-term FAIR access to high quality, multi-disciplinary geoscientific data from Iceland.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Talk

Meeting the public where they are at by creating accessible resources with familiar tools

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To encourage the geo-conservation of outcrops or geosites with geoheritage significance it is essential to communicate this value to the public through accessible science. To avoid inaccessibility, in part, caused by the unengaging design of typical research outputs, we produced alternative research outputs. Davila-Harris (2023) describes the stratigraphic layers exposed in the erosive cliffs of Puertito de Adeje, South Tenerife, comprising geological formations that illustrate the volcanic activity of Las Cañadas. One of these formations is a welded ignimbrite, associated with a high-temperature eruption. The eruptive processes that can be inferred from the study of these units are of vital scientific and cultural significance regarding the volcanic risk to the highly populated municipality of Adeje. However, the Davila-Harris (2023) article is somewhat inaccessible due to the Journal of Volcanology and Geothermal Research requiring organisation access or payment and the manuscript being 71 pages long. True accessibility requires digital platforms that host resources that utilise varying tools/formats familiar to the public. GeoTenerife produced an interactive, scrollable, and clickable Google My Maps resource, hosted on the VolcanoStories website. This has garnered 5,000+ views, thus, transforming complex scientific literature into accessible science. Google My Maps allows scientists to collate: photography taken in situ, summaries of unit description and interpretation, simple diagrams and YouTube videos transposed onto a map to indicate geographical location. Using this technique of transforming research into familiar tools, scientists can increase the outreach of volcanological research and thus awareness of volcanic risk.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Data and service management of the EPOS Volcano Observations Thematic Core Service by the European volcanological community

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The Volcano Observations Thematic Core Service (VOLC-TCS) is one of ten core services forming the European Plate Observing System (EPOS). The objective of the VOLC-TCS is the implementation of a technical, financial, and legal framework to (i) strengthen the European volcanology community and (ii) provide virtual access to the community's data, data products software and services from volcanoes in Europe and European overseas territories. The efforts of the VOLC-TCS began prior to the appointment of EPOS as an ERIC and have followed a long-term work plan that started in 2002. The main challenges have consisted in (1) data heterogeneity regarding technical and legal aspects (e.g. different data policies among the data providers, different purposes for the use of data), (2) the consistency of the VOLC-TCS' products with the overall service provision of EPOS, which merges services from different Earth Science communities, (3) the harmonisation of the data and products with standards defined by other TCSs, and (4) the implementation of the community Gateway to expose and enable access to services not fully EPOS compliant or to services implemented by institutions outside the EPOS, and to create a platform acting as an interface between the VOLC-TCS and data infrastructures operating at a global level (e.g. WOVOdat). Based on the experience gained and the results achieved, we report on the state of the art of the VOLC-TCS since 2018 and propose future actions to address some of the main technical challenges and measures to ensure mid-to-long term sustainability of the services.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Unleashing the Power of Open Data: Lessons from History and Paths Forward

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The paradigm of open data has transformed numerous scientific fields, enabling unprecedented collaboration, innovation, and societal impact. We have already learned from successful historical projects where open data had a groundbreaking impact. The Human Genome Project is a testament to how open data sharing can catalyze advancements across disciplines and the International Seismological Centre's global earthquake catalog revolutionized seismic research and monitoring. Openness fosters interdisciplinary insights and accelerates solutions to global challenges. However, the path to fully open data in volcanology is fraught with obstacles. Institutional resistance, lack of standardization, and concerns about intellectual property rights persist as barriers to achieving FAIR (Findable, Accessible, Interoperable, and Reusable) data practices. We need actionable strategies to overcome these hurdles, emphasizing the importance of establishing community-driven standards, incentivizing data sharing, and leveraging technological advances for secure and transparent data exchange. By addressing challenges head-on, learning from historical successes, and championing new paradigms, the volcanology community can harness the full potential of open data, driving scientific progress and enhancing societal resilience against volcanic hazards. The transformative potential of open data is greater than it has ever been.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

The Geohazard Digital Twin Component as a means for Open Science in Volcanology

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Modern EO (Earth Observation) has dramatically increased our ability to monitor volcanological phenomena. However, there is still a weakness of technological solutions for data access, processing and interpretation, following Open Science principles. The Digital Twin Components (DTC) are a complex of software and data services needed for Earth System digital replicas. ESA (European Space Agency) supports the latest advances in EO-based science to deploy new DTCs. The Geohazard DTC is one of them, currently under development by INGV, CSIC and BIRA, with the technological support of TerraDue through the GET-it project. The proposed Geohazard DTC is based on the exploitation of multi-sensor EO data and AI techniques. In particular, it has been designed to leverage Copernicus data and advanced algorithms, for generating information services encompassing the whole spectrum of volcano- (and seismic-) related geohazards. The main modules available in the Geohazard DTC are: - GEOMOD: performs geodetic data direct and inverse modelling; - FALL3D: models and forecasts volcanic ash/SO2 clouds; - GPUFLOW: models the evolution of lava flows; - DAMSAT: performs change detection. The DTC is planned to serve *What-If Analysis for Disaster Preparedness*, to allow users to assess potential interventions and their impacts on disaster outcomes, thereby enhancing preparedness and mitigation strategies. The engaged stakeholders include policy and decision makers, emergency managers and scientists. The use cases for the demonstration of the Geohazard DTC prototype are the Mount Etna (Italy) 2018 eruption and the La Palma (Spain) 2021 eruption, and the Central Italy 2016 earthquake sequence.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Tephra: from reconstructing past eruptions to forecasting and modelling future events – A Special Publication

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Tephra produced during explosive eruptions can have devastating consequences on communities and infrastructure. By better understanding its generation, transport and deposition, we can gain further insight into how to better plan for and mitigate against the impacts of volcanic eruptions. Advances in science over the past two decades and more have led to significant developments in unravelling processes, the reconstruction of past events and forecasting and modelling of ongoing and future eruptions. Here, we present a new Special Publication book volume open to submissions on the science of tephra. As a collaboration between the Geological Society of London and American Geophysical Union, and led by the IAVCEI Commission on Tephra Hazard Modelling, we welcome research articles related to tephra hazard research and applications. This includes articles related to tephra processes in explosive eruptions, reconstructing eruptive histories using tephra and tephra dispersion, deposition and hazard modelling and forecasting. Through a volume on the latest research into tephra, we aim to identify the status, gaps and future directions of the science, while collating cutting edge articles that significantly advance our understanding of explosive volcanism.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

WOVOdat Web Service Data Retrieval System for Comprehensive Volcano Monitoring

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WOVOdat, the World Organization of Volcano Observatories database, serves as a centralized repository for global volcano unrest data. Built on a MySQL structure, it is accessible through the user-friendly web interface, **wovodat.org**, providing a valuable resource for researchers and decision-makers. We introduce a web service tool that simplifies access to WOVOdat's extensive datasets, enabling users to efficiently retrieve tailored data using structured query scripts. Key parameters, such as volcano name, data type, and time range, can be customized to extract relevant data in a standardized format over HTTP. The web service tool is designed to handle large datasets effectively, offering the volcano community a user-friendly and flexible approach to accessing unrest data. Integration with an Application Programming Interface (API) further enhances the tool's functionality by enabling automated data retrieval and seamless integration with external tools, supporting advanced analyses and workflows. By streamlining access to WOVOdat's comprehensive datasets, the tool facilitates the identification of precursory patterns, improves eruption forecasting, and enables comparative studies of volcanic behavior across systems. This functionality deepens our understanding of volcanic processes and hazards, supports analogue studies, and contributes to advancing knowledge of volcanic activity and its associated risks. The tool represents a significant step forward in leveraging digital technologies for volcanic research and risk mitigation.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Results of round-table discussions on the future of Volcanic and Igneous Plumbing System research

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We designed and led a series of round-table discussions as part of the 1st IAVCEI Commission on Volcanic and Igneous Plumbing Systems Conference held in Liverpool, UK in 2024 to learn about perceptions of scientific and societal challenges in the VIPS research community. Delegates worked in multidisciplinary groups, including representatives across diverse career stages, from PhD students to senior researchers, and spanning academia and volcano monitoring agencies. Each group has a pre-designated notetaker and was first asked to discuss: What are the unresolved problems related to Magma Plumbing Systems, why are these important and why are they unresolved? Four key unresolved problem themes were raised: 1) Issues related to the geometry and evolution of magma reservoirs and mush systems, 2) the timescales and dynamics of magma intrusion and eruption triggers, 3) interactions between magmatic, hydrothermal, tectonic and environmental factors, and 4) necessity for better constraints on physical and chemical properties of magmas, mushes and rocks. It was agreed that these themes were important for hazard mitigation, resource assessment and use, as well as for general advancement in the improvement of models. Disciplinary silos, data and model limitations, and constraints on physical and financial resources were all identified as obstacles to solving them. The groups also discussed advantages and challenges of working with multi-disciplinary methods and techniques, how VIPS research can aid in volcano monitoring efforts, and finally to deliberate the most important VIPS-related questions we should focus on over the next 5, 10 and 20 years.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Teaching LAHARZ at CSAV is quicker with VICTOR: using the cloud-based VICTOR platform for an international lahar modeling course

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In 2024, as part of the Center for the Study of Active Volcanoes (CSAV) International Training Course, we used the VICTOR (Volcanology Infrastructure for Computational Tools and Resources) platform to teach the week-long LAHARZ lahar modeling component of the course for the first time. The CSAV lahar modeling module is usually taught using the 2014 USGS version of LAHARZ designed to run from the ArcGIS toolbox. While this version of LAHARZ has been updated to run in ArcGIS Pro and is still available, we wanted to test the use of a new open-source, Python version of LAHARZ, developed by Keith Blair, with the CSAV course. To streamline the course redesign, we enlisted the help of VICTOR, a cloud-based JupyterHub platform on which users can run models. With both LAHARZ and QGIS available through VICTOR, we were able to run the entire course from the platform. We also used VICTOR to easily share class files and presentations, to download digital elevation models (DEMs) needed for lahar modeling, and to streamline the course workflow. CSAV students, who are usually volcano observatory staff members from countries with limited computing resources, can now use the VICTOR platform for any future lahar, lava flow, pyroclastic flow, and tephra modeling. We also used the teaching experience and course feedback to implement new features in LAHARZ and VICTOR. This presentation describes challenges faced and our experience with the platform, presents our ideas for the future, and solicits conversation with other users or educators.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Network for Observation of Volcanic and Atmospheric Change (NOVAC): Community technology development and implementation for volcanic gas monitoring

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The Network for Observation of Volcanic and Atmospheric Change (NOVAC) is a community of volcano observatories and research institutions that together develop and apply ultraviolet differential optical absorption spectroscopy (DOAS) instruments to measure volcanic sulfur dioxide (SO_2) emission rates. The collected data are used for assessment of volcanic activity, eruption forecasting, research on volcanic processes, and studying the atmospheric impact of volcanic degassing. Collectively, the NOVAC institutions run the largest global instrument network for monitoring volcanic gas emissions, monitoring degassing at 54 volcanoes across 20 countries. Here, we review recent developments in remote sensing instrumentation, retrieval methodologies, software packages and data visualization tools stemming from the NOVAC community. Updated scanning DOAS instruments are designed to withstand harsh environmental conditions, including snow, rime ice, and ash fall. Recently developed data-analysis methods allow for correction of radiative transfer errors such as light dilution and take variable plume heights into account. New NOVAC software features allow continuous spectrometer calibration based on the measured position and shape of Fraunhofer lines, as well as quantitative detection of bromine monoxide (BrO) in volcanic plumes. Additionally, novel data-visualization tools allow custom plotting of SO_2 emission rates from any volcano in the network, as well as direct access to the operational, real-time data. Through joint technology development, regular workshops, and support from organizations such as USAID, UNESCO, and EGU, NOVAC provides a community for partners to share technology, training, and volcanic gas monitoring experience with researchers and engineers from institutions all over the world.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Experiences with open volcano monitoring data at GeoNet, Aotearoa New Zealand

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The GeoNet programme at GNS Science is the primary agency for collecting, managing, and delivering volcano monitoring data in Aotearoa New Zealand. It is also responsible for monitoring and collecting earthquake, landslide, and tsunami data. Open data (and metadata) principles are at the core of GeoNet. Volcano datasets include data collected automatically from seismographs, acoustic-infrasound sensors, GNSS receivers, webcams, scanDOAS systems, and a range of environmental sensors, and, data collected manually during fieldwork at volcanoes. All datasets can be accessed via a web-browser and an API. One in-house developed application (Tilde) delivers most of the low-rate volcano time-series data. Most datasets are also available through the AWS Open Data Program, providing free access to support users wanting large volumes of data, or to develop cloud-based applications. We actively work to boost FAIR data, and prioritise ease of access in our application design philosophy. We will discuss our experiences with managing and delivering volcano monitoring data. Including working in a multi-peril environment, managing automatic data vs manual collection, leveraging pre-existing data standards and formats, considering Indigenous data governance in New Zealand, and concerns about possible data mining. GeoNet volcano data are available at www.geonet.org.nz.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

How we improved FAIR for volcano monitoring data at GeoNet, Aotearoa New Zealand

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The GeoNet programme at GNS Science is the primary agency for collecting, managing, and delivering volcano monitoring data in Aotearoa New Zealand. It is also responsible for monitoring and collecting earthquake, landslide, and tsunami data. We actively work to improve the FAIR of our data. We evaluated FAIR compliance using the Australian Research Data Commons (ARDC) FAIR data self-assessment tool, modified for our use (Mavroeidi and Rattenbury, 2022). We first scored our data in 2021, and repeated that process in 2024. Due to difficulty in comparing our FAIR scores with those from other assessment tools, our primary focus has been using results to drive improvements in GeoNet data management practices. In 2021, all five volcano-specific datasets that were assessed ranked in the bottom half of all GeoNet FAIR scores, sparking significant efforts for improvement. In 2024, volcano datasets scored substantially higher. The most valuable improvements were to add datasets to GNS Science's Dataset Catalogue and generate a Digital Object Identifier (DOI) for each dataset. These two efforts hugely increased dataset Findability scores. In other cases, we worked on datasets that were only available upon request, and provided an open access mechanism and documentation as well Dataset Catalogue entries and DOIs. We will compare our 2021 and 2024 FAIR scores, discuss our FAIR scoring procedure, talk about which activities improved FAIR scores, and which did not. **Mavroeidi, M.; Rattenbury, M.S. 2022** FAIR Principles applied to high-value geoscience datasets. Lower Hutt, N.Z.: GNS Science. *GNS Science report 2021/62.* 39 p.; doi: 10.21420/88HQ-9792.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Management of the Volcanological Data: An overview

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Volcanological data are heterogeneous in nature. They come from field observations, ground based and remote sensing instruments, permanent stations or campaign deployments, and include geochemical analyses, geophysical time series, images, video, and other data types. These data are collected, processed, and stored in different formats, with different objectives, with varying levels of support and infrastructure, and are managed by diverse institutions worldwide (observatories, universities, and research institutions). Considering this framework, volcanologists have adopted different approaches and solutions to manage their data. The range of data management solutions reflects the goals with which the data are collected, e.g. scientific monitoring, hazard mitigation/civil protection, research projects. Technological advancements have added complexity to data management. During recent decades, data acquisition has dramatically increased in both quantity and quality, and previously analog data are now routinely acquired in digital formats, resulting in larger and more complex datasets. The implementation of the "Open Science" framework and adherence to the FAIR (Findability, Accessibility, Interoperability, and Reusability) principle pose both technical and policy challenges for enhancing data access within the volcanological community. This contribution aims to give an overview of the current strategies and best practices adopted by the volcanological community for data management and distribution, as presented in a recent Special Issue of the Bulletin of Volcanology. The topics covered include data standardization and interoperability, data archiving, long term curation, and the various infrastructures supporting science and surveillance activities.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Global Perspectives on Volcano Monitoring: Automation, Standardization, and Capacity Building

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We are advancing towards automation and standardized methodologies for processing volcano monitoring data, leveraging datasets from global volcanoes. Funded by Singapore National Research Foundation, this five-year initiative utilizes publicly accessible seismic waveform datasets, existing collaborations, historical volcanic activity records, and eruption phases. By integrating automation into data workflows, the project accelerates analysis, enhances accuracy, and minimizes human error. Standardized protocols ensure systematic data handling, promoting reliable findings and enabling effective comparisons across volcanoes and time periods. Together, these approaches improve decision-making for volcanic hazard mitigation, expedite analysis, and contribute to comprehensive repositories like WOVOdat, fostering global scientific collaboration. The project places a strong emphasis on capacity building through open-source tools and training programs, actively engaging students and volcano observatory staff. Participants gain hands-on experience analysing seismic activity related to volcanic processes before, during, and after eruptions. Feedback from observatory staff ensures ground-truth validation and guides improvements to the techniques and tools developed. By encompassing diverse volcanic activities, magma compositions, and tectonic settings, the project aims to advance understanding of volcanic processes and enhance preparedness efforts for volcanic hazards worldwide.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Enhanced global monitoring of volcanic plumes through integration of LEO and GEO retrievals to support volcanic observatories and aviation stakeholders

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The effect of volcanic eruptions can cross borders, threatening aviation and local communities. Expanding our understanding of volcanic processes is essential. In this context, satellite datasets are playing a crucial role. We present our activities, as part of the Belgian Natural hAzards Monitoring from SATellites (NAMSAT) project, aiming at developing a web-based data service and portal dedicated to airborne hazards, providing near-real time access to satellite volcanic plume observations and added-value products. Our work builds on the SACS early warning system (https://sacs.aeronomie.be), which utilises low Earth orbit (LEO) satellite data to observe and detect aerosols and SO_2. While LEO instruments provide selective detection, their revisit times are limited. The NAMSAT project aims to enhance SACS by incorporating geostationary Earth orbit (GEO) satellite data. Using linear discrimination techniques with spectrum classes to construct covariance matrices, we detect aerosols (ash/dusts or ice crystal) and SO_2 from sensors like FCI (onboard MTG), ABI (onboard GOES-W and GOES-E), and AHI (onboard HIMAWARI-9). This approach enables data delivery within minutes after sensing and leverages the global GEO-Ring (ensemble of GEO-sensors). This presentation will highlight the added-value products, including time-series of key observations such as SO_2 mass, plume height, and aerosol/ash detection over fixed or user-defined volcanic areas. These products are designed to address the needs of volcanological users, providing timely data for both pre-eruption monitoring and real-time eruption scenarios. Additionally, aviation stakeholders will benefit from enhanced situational awareness enabled by improved GEO-based detection. Recent eruptions are used to demonstrate the capabilities of the NAMSAT service.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

On the use of dense seismic deployment and data processing at volcanoes; a collaborative effort

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Seismology is the backbone of many volcano monitoring systems. Ground vibrations can be monitored using conventional seismometers, ranging from high-hand broadband instruments to geophones with lower performances but competitive prices. Over the last years, the volcano seismic community has seen tremendous advance in software as well as instrument/technique development. At volcanoes, fiber optic cables interrogated by distributed acoustic sensing have shown promising results providing unprecedented spatial resolution on the seismo-acoustic wavefield radiated, and opening new avenues for volcano monitoring. We first present recent observations acquired using fiber-based technologies. At various volcanoes (e.g., Laacher See (Germany), Poás (Costa Rica)), we have monitored underwater volcano degassing using both fibers and hydrophone measurements. In Iceland, we have instead deployed or used fibers in the ground to monitor strain variations associated with eruptions in the Reykjanes peninsula (Iceland), or image the shallow subsurface. The other part of this contribution will review open source softwares that have been developed to monitor the subsurface and tremor using continuous ground vibrations acquired by seismometers and fiber optic cables. We will present the latest developments taking advantage of the MSNoise package to analyse ambient seismic noise, detect subtle changes in the medium, and compute surface wave kernel sensitivity across different frequencies. This software, as well as tremor-dedicated Covseisnet package or other tremor-based forecasters, are now running in real-time at various volcano observatories. We will review their advantages but also challenges, for example the problems of cross-comparison for various volcanoes through WOVOdat that require standardised products.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Volcanological Software as a Service to the community

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Scientific software is being more and more requested 'as a service' from a variety of stakeholders, including fellow researchers, students, policymakers, as well as the general public. Volcanological software is no exception, as testified by recent EU-funded initiatives such as ChEESE-2p, focused on using HPC solutions to model hazard and risk; Geo-INQUIRE, devoted to making geo-scientific products (data, software, infrastructure) available to foster curiosity-driven research; DT-GEO, aimed at creating Digital Twins for geophysical extreme events. These efforts have been favored by EPOS (European Plate Observing System), a European Research Infrastructure Consortium (ERIC) committed to enabling excellent science by sharing of Solid Earth science research products and services. In this context, software needs to obey the same principles that guide data products: it should be Findable, Accessible, Interoperable and Reusable (FAIR). To this aim, a common effort should be sustained to maintain a community metadata catalogue of the available software; to develop Virtual Access platforms and Virtual Environments (for non-HPC software) able to make data and software interoperable through APIs; to promote Transnational Access initiatives to make HPC software accessible; and to support open-source software. We showcase here examples of effective software sharing by means of virtual and trans-national access schemes, that include training and support which become crucial as the software increases in complexity. Feedback between modelers and the wider volcanological community is key to advance in such interdisciplinary subjects as volcanic processes and hazard, and must be fostered by openly sharing resources, and providing support for their responsible use.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Gales: an open-source volcano simulation toolbox

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We present the open-source Volcano simulation toolbox Gales (https://gitlab.com/dgmaths9/gales) that has been under continuous development for the past > 10 years. Gales employs the Finite Element Method to solve partial differential equations (PDEs). It is written in C++ and utilizes the HPC library Trilinos for its implementation. Gales offers several state-of-the-art solvers for a) transient heat transfer; b) compressible-incompressible flow of Newtonian and non-Newtonian fluids; c) static and dynamic response of elastic and viscoelastic materials; d) multiphysics solvers: thermoelasticity and Fluid-Solid Interaction (FSI). The code has undergone thorough benchmarking on various test cases, ranging from engineering benchmarks to problems with analytical solutions. Gales includes a suite of models that accurately describe the properties of multi-component, multiphase magmas. The flow solver is capable of modeling magma transfer and mingling from under-saturated magma conditions deep into the crust to rapidly accelerating conditions along volcanic conduits. The solid solver in Gales accounts for rock heterogeneities, free surfaces, and the real topography of volcanic regions. It enables the computation of deformation, stress, strain, and tilt at the Earth's surface Gales plays a crucial role in several EU projects, including DT-GEO (https://dtgeo.eu), IMPROVE (https://www.improve-etn.eu/), and KMT (https://kmt.is). Numerical simulation results from applications of Gales to the volcanic environment have led to several original insights into the complex interplays between cooling, crystallization, degassing, and internal dynamics in magma bodies and their associated signals. We invite a broad community of geoscientists interested in simulating a variety of geodynamic processes to use Gales in their research.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

A streamlined tephra inversion workflow in the cloud with VICTOR

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The inversion of field observations to infer eruption parameters for past eruptions is a fundamental tool in volcanology. Quantitative inversion requires understanding of statistics, data science, and the limitations of the forward model, a challenge in interdisciplinary research, collaboration, and education. It is thus beneficial to provide the community with access to streamlined workflows for inversion. Here, we couple the Metropolis-Hastings algorithm with the volcanic ash transport model Tephra2, and present the coupled algorithm as a new method to estimate the Eruption Source Parameters of volcanic eruptions based on mass per unit area or thickness measurements of tephra fall deposits. Outputs of the algorithm are presented as sample posterior distributions for variables of interest. We demonstrate the algorithm and the workflow works for both synthetic data and observations from real eruptions. As a Markov chain Monte Carlo (MCMC) algorithm, Metropolis-Hastings incorporates prior knowledge, quantifies the uncertainty, captures correlations between parameters, and assumes no simplification in sampling from the posterior probability distribution The workflow is implemented on the Volcanology Infrastructure for Computational Tools and Resources (VICTOR), a cloud-based cyberinfrastructure platform supporting the volcanology community. It is streamlined through a Jupyter Notebook, guiding the user through parameter and data input and output analysis. Basic elements in the algorithm and how to implement it are introduced throughout the notebook. By utilizing the features of the shared platform VICTOR, it openly shows the inside of the inversion “black box” in a simplified way, making it accessible for both experienced researchers and students

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Update on the Tephra Information Portal (TIP)

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We are developing a sustainable information framework to address the lack of standardized, machine-readable, FAIR-compliant data within the global tephra research community. The Tephra Information Portal (TIP) is envisioned as a central point of access to data resources for the community of researchers who study tephra or need access to tephra data. The TIP is a collaboration between the tephra community and the IEDA2 (EarthChem, SESAR) data facility as part of the prototyping of the Framework for FAIR Data Communities (FFDC). We are building on existing cyberinfrastructure at IEDA2 and other tephra resources and data, including StraboSpot, GeoDIVA, TephraBase, and others. Objectives include: (a) helping researchers select a data repository; (b) ensuring consistent formats with rich metadata; (c) creating a central catalog with a compiled critical mass of curated data; (d) serving as a single point of data discovery, access, and use; (e) providing protected workspaces with user authentication and management; (f) incorporating discipline-specific standards; (g) supporting a next-generation toolkit and access mechanisms; and (h) responding to community needs. As a first step in this newly funded project, we held a 3-day workshop (November 2024) to bring together tephra researchers, database developers and software engineers to begin envisioning the TIP and establishing collaborations with existing tephra data resources. This project leverages a decade of international tephra community building and consensus development and a strong track record of engagement to prototype and test cyberinfrastructure, produce training materials, educate users, and increase the accessibility of research tools and data.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Tephra Fusion 2.0 - Creating the future of FAIR tephra data

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In 2022, a decade of international tephra research community-building, engagement, and consensus-development led to publication of best practice recommendations. This tephra community work contributes to a broader movement toward open science and FAIR practices - Findable, Accessible, Interoperable, and Reusable data. Comprehensive tephra data best practice recommendations are described by Wallace et al. (2022 https://doi.org/10.1038/s41597-022-01515-y), and provided as spreadsheets housed at Zenodo covering physical and geochemical information (Abbott et al. 2022 https://doi.org/10.5281/zenodo.3866266). The recommendations are implemented into the StraboSpot app for field observations, SESAR templates for samples, and EarthChem templates for analytical methods and geochemistry (https://www.earthchem.org/communities/tephra/). We encourage all tephra researchers to adopt the recommended practices and evolving toolkit to maximize the value and impact of their data. The workshops Tephra Fusion in 2022 (https://www.tephrochronology.org/cot/Tephra2022/) and Tephra Data Systems in 2023 helped envision a future built on the best practices foundation, and on that basis we have launched Tephra Fusion 2.0. A key component is the Tephra Information Portal (TIP) which received NSF funding in 2024 to prototype cyberinfrastructure, produce training materials, and increase the accessibility of tools which improve tephra data discovery and archiving (see also companion abstract). This presentation will introduce the planned functionality and services of the TIP, specifically focusing on support for user workflows and the integration of tephra data, and how the TIP will continue to meet the needs of the tephra research community.

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Allocated presentation: Poster

Enabling Open Volcanology With Community-driven Services for Open & FAIR Data and Samples

Kerstin Lehnert*[1], Lucia Profeta[1]

Open Volcanology requires research infrastructure that supports the persistent sharing and curation of research products including data, software, and samples. IEDA^2 is a unique collaborative data infrastructure funded by the US National Science Foundation that operates data services relevant for the volcanology community, including publication and preservation of geochemical, geochronological, mineralogical, petrological, and other sample-based data (EarthChem Library, PetDB, Library of Experimental Phase Relations, EarthChem Portal); human- and machine-readable interfaces for accessing high quality, curated data; and a digital environment for physical samples that support discovery and reuse of samples and their integration with the digital research data ecosystem (System for Earth & Extraterrestrial Sample Registration SESAR^2). The EarthChem Portal

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By combining the operation of technical infrastructure, data curation, user support and training, community engagement, and international collaboration with relevant data facilities IEDA^2 enables open, reproducible, and transparent science practices in volcanology. Among IEDA^2's services that are specifically tailored to volcanology is the Volcano Portal that allows researchers to simultaneously find and access data in multiple data systems that store and manage data for volcanoes, including the Smithsonian Institution's Global Volcanism Program database of volcanic activity data; the EarthChem Library and the EarthChem Portal; the SESAR sample catalog; the Italian MaGa database of compositional and flux data of gases released at volcanic and non-volcanic degassing sites; OpenTopography (LIDAR data); and data system of the EarthScope Consortium. Partnering with the tephra community IEDA^2 is now developing the Tephra Information Portal which will also be presented in this session.

Theme: 7. Communication in Volcanology

Session 7.5: Open volcanology: open science initiatives for sharing data, tools, technology, and research

Allocated presentation: Poster

Open Science in Chilean Patagonia: Enhancing the Volcanic Context through Collaboration and Communication in Patagonia, a Region of Extremes

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Chilean Patagonia represents a unique scenario where multiple geological hazards converge with extreme logistical challenges and dispersed population patterns. This region, characterized by severe weather, rugged terrain, and limited connectivity, hosts numerous active volcanoes that differentially impact communities, infrastructure, and ecosystems across its vast territory. From densely populated areas to remote settlements, from critical infrastructure to pristine environments, each volcanic system presents distinctive monitoring and risk management challenges, while coexisting with glaciers, fjords, and complex tectonic systems. This work demonstrates the importance of enhancing information gathered through territorial initiatives that enable instrumentation and volcanic hazard management through collaborative networks that integrate scientific institutions, civil protection agencies, and local communities. This enables the exchange of relevant data and information not only among researchers but also facilitates bidirectional communication with local observers and authorities, creating an information ecosystem that strengthens volcanic risk management across these diverse contexts. Effective collaboration and communication, which enables a transversal knowledge network, shows that partnerships between institutions and communities have generated more robust and contextually appropriate early warning systems. These collaborative networks have proven especially valuable during emergencies, where fluid communication among all stakeholders is essential for addressing the varied impacts of volcanic activity on different populations and territories.

Theme: 8. The future of volcanology, a bundle of sessions organized by the ECRs (Early Career Researcher) of IAVCEI

Session 8.1: The future of volcanology, a bundle of sessions organized by the Early Career Researchers of IAVCEI

Allocated presentation: Talk [Invited]

Data in Action: Towards Timely and Accurate Monitoring of Volcanic Behavior using Near-Real-Time, Analysis-Ready, and GIS-Ready Datasets

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Timely and accurate information on volcanic systems is essential for mitigating the societal impacts of eruptions. Achieving this requires leveraging near-real-time, analysis-ready, and GIS-ready datasets that simplify complex data interpretation while enabling advanced spatial analysis and visualization. NASA-JPL's ARIA and OPERA projects are at the forefront of these efforts, making global Earth Observation products from SAR and optical missions more accessible, user-friendly, and actionable. By streamlining data delivery and usability, these initiatives empower researchers, and decision-makers with the critical insights needed to anticipate and mitigate volcanic hazards more effectively. In this presentation, we will demonstrate how ARIA and OPERA products facilitate near real-time volcanic monitoring and explore their potential for early warning and eruption forecasting. By integrating these datasets with models and/or advanced computational methods—including Bayesian inversion, data assimilation, and machine learning techniques—we aim to enhance the accuracy and timeliness of eruption forecasts. These next-generation frameworks can revolutionize volcanic hazard assessments, enabling rapid, precise warnings that strengthen community resilience, protect infrastructure, and ultimately redefine the future of volcanic risk mitigation.

Theme: 8. The future of volcanology, a bundle of sessions organized by the ECRs (Early Career Researcher) of IAVCEI

Session 8.1: The future of volcanology, a bundle of sessions organized by the Early Career Researchers of IAVCEI

Allocated presentation: Talk [Invited]

Insights on magma dynamics from integrated observational, experimental, and numerical methods

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Observations of volcanic eruptions are our primary source of information on the dynamics of magmatic systems. However, interpretation of the complex reality requires experiments using analogue or natural materials. Numerical models can bridge the temporal and spatial scales of experiments and the Earth, and identify dynamic regimes and controlling processes. Each of these sources are powerful individually, but genuine integration of these methods leads to deeper insight. Here, we use numerical models to plan and interpret high-temperature vesiculation experiments on natural obsidian at a range of spatial scales (5 mm to 18 cm diameter) and reveal the role of shear on promoting bubble connectivity and resisting bubble growth. Joint numerical simulations of water content and speciation, CO2 concentration, and vesicle abundance and texture compared with natural samples recovered during drilling of the IDDP-1 borehole reveal in unprecedented detail the response of magma to induced decompression and cooling. Calibration of the numerical models on confined vesiculation experiments, small and large, and on natural samples with a controlled pressure-temperature history, improves our confidence in modeling meter-scale volcanic conduits. We discuss opportunities for and the importance of synergistic multi-methodological studies in understanding complex volcanic processes.

Theme: 8. The future of volcanology, a bundle of sessions organized by the ECRs (Early Career Researcher) of IAVCEI

Session 8.1: The future of volcanology, a bundle of sessions organized by the Early Career Researchers of IAVCEI

Allocated presentation: Talk [Invited]

Advancing in-situ observations of magmatic processes: development of an X-ray Transparent Internally Heated Pressure Vessel for High-Pressure, High-Temperature synchrotron imaging

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A novel X-ray transparent Internally Heated Pressure Vessel (IHPV) has been developed to enable synchrotron X-ray radiography and microtomography at high temperatures (up to 1250°C) and pressures (up to 200 MPa), providing in situ observation of material processes. Tested at DLS (United Kingdom) and ESRF (France) synchrotron facilities, the IHPV has been used to study vesiculation and crystallization in basaltic magmatic systems, offering insights into key processes like crystallization, degassing, gas bubble formation, and magma mixing. Traditionally, high-pressure, high-temperature properties of materials such as geomaterials and alloys were analysed in quenched final products at room temperature. Recent advances in imaging techniques like two-dimensional radiography and three-dimensional microtomography allow for direct observation of processes such as melting, vesiculation, and crystallization in real time. This development is particularly valuable for quantifying vesiculation and crystallization in volcanic systems under natural magmatic conditions, improving our understanding of magma evolution and eruption forecasting. Previous studies have been limited to shallow depths due to apparatus constraints, but this novel IHPV enables experiments at deeper crustal pressures, where critical processes occur. In addition to its applications in geosciences, this technology can be applied to material science, studying high-temperature and high-pressure behaviours in various materials.

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Session 8.1: The future of volcanology, a bundle of sessions organized by the Early Career Researchers of IAVCEI

Allocated presentation: Talk [Invited]

Modernizing tephra studies at the Alaska Volcano Observatories: An applied Data Science Approach

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This work highlights the workflow for constructing eruptive histories via tephra correlations at the Alaska Volcano Observatory. Recently, our work has taken an applied data science approach, combining the fields of volcanology, compositional data analysis, petrology, and statistics. Using compositional data analysis techniques, we mitigate many of the pitfalls that commonly plague application of statistical tests to compositional data including unit sum constraints and mathematical artifacts. We then show how we can link geologic units, regardless of their source, common statistical tests when geometric means are and proper data transformations are considered considered. A probabilistic assessment of the most likely source volcano is then created using two different approaches: machine learning predictions and minimizing Mahalanobis distances. Variables considered for linking tephras to source volcanoes are incompatible trace element ratios commonly used in petrology to discriminate between unique magmatic sources. Finally, we use cooperative game theory to help explain which variables are most important in identifying each volcano and conformal prediction to assign accurate uncertainties to statistical predictions. Combined, these steps allow for the implementation of a robust methodology for assigning volcanic sources to tephra fall deposits, allowing more accurate eruptive histories to be constructed.

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Session 8.1: The future of volcanology, a bundle of sessions organized by the Early Career Researchers of IAVCEI

Allocated presentation: Talk [Invited]

Pen to Paper: a celebration of the enduring power of the sketch in a digital age

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I will discuss the history of sketching in geology and argue for its enduring relevance in the digital age. I will begin with ancient cave paintings depicting volcanoes, conveying our millennia-long fascination and compulsion to illustrate them. Moving to the advent of geological science, I will discuss the emerging art of the geological field sketch and its purpose – to observe features of the landscape and from those observations interpret geological processes. Art historians (e.g., John Berger) argue that the singular power of drawing is found in the quality of our looking, and I will consider how their arguments apply to geological and geology-adjacent sketches (e.g., Alfredo Mackenny, Alfred Wainwright, my own work), that contemplate both the natural landscape and our place within it. I will discuss how this duality is relevant to modern geology, which increasingly considers the mutual influence of humans and the Earth on shaping each other. This forms my closing message, which urges that the act of putting pen to paper (or stylus to iPad) to draw has an enduring power in an age of generative AI. This demonstrates that compelling geological maxim: The past is the key to the present – and the future!

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Allocated presentation: Talk [Invited]

Living on the Edge of an Active Volcano: Human Dimensions of Population Exposure to Volcanic Hazards – Lessons from Goma, Eastern DR Congo

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Volcanic disasters provide valuable opportunities to gain insights and improve disaster risk management. While volcanology traditionally emphasises the physical processes and risk assessment associated with volcanic activity, understanding the societies living on the edge of an active volcano is critical for effective risk assessment. In Goma, Eastern DR Congo, local communities navigate a complex interplay of economic, social, and cultural factors that shape their decision to remain or resettle in high-risk zones, thereby maintaining or increasing their exposure. This presentation examines the drivers that compel people to rebuild on the lava flows from the 2021 Nyiragongo eruption and their adaptive strategies for living in high CO2-prone areas in the Goma region. The findings show that a strong attachment to land and its accessibility are the primary motivators for returning to the lava flows. Additionally, the need to restore community life and preserve pre-existing communal identity is crucial, as community support significantly aids survival, particularly in areas lacking basic public services. For those living in high CO2 concentration zones, risk perception varies spatially. Residents near marked hazardous areas perceive higher risks compared to those in unmarked zones, despite sometimes similar CO2 concentration. It suggests that awareness campaigns positively influence population behaviour. To mitigate the effects of the gas, low-income households use waste materials to block diffusion, while wealthier residents invest in sealing their properties. In both scenarios, attachment to Goma, the security and stability it provides are key factors driving habitation in high-risk areas. These insights provide a new perspective on understanding the human dimension of volcanic risk exposure. After an eruption, people tend involuntarily to 'replace' or/and 'increase' their exposure to hazards as long as there is an available living space. Therefore, the development of targeted and effective disaster risk management strategies needs to take into account these human dimensions.

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Session 8.1: The future of volcanology, a bundle of sessions organized by the Early Career Researchers of IAVCEI

Allocated presentation: Talk [Invited]

The utility of topography in disentangling volcano construction, erosion, and magmatic histories

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Volcanic edifices represent a long-term convolution of magmatism, volcanism, erosion, and climate. Edifices grow through both subsurface intrusions that uplift the surface from below, and lava flows and ash deposits that mantle the surface from above. Meanwhile, these periods of growth are temporally-juxtaposed against the longer-term backdrop of climate- and gravity-driven erosive processes that degrade the edifice. Deconvolving these signals is challenging, yet presents new insight into understanding volcanic terrain as an interface between crustal and surficial systems. Here, I demonstrate the utility of incorporating geomorphology-based analyses into volcanology to resolve construction histories, volcano-climate interactions, and connection to underlying crustal magma structure. Beginning with La Réunion, I show that erosion patterns correlate with volcano unit age, and that drainage basin morphologies are indicative of rainfall gradients across the island. Expanding to sets of stratovolcanoes, I demonstrate that morphometrics of edifices and their drainage basins are strong temporal indicators for volcanic activity ages. Finally, in the U.S. Cascades, I show how arc-scale distributions of edifice erosion volumes relate to both precipitation gradients and volcano locations, suggesting potential feedbacks between climate, erosion, topography, and shallow-crustal magmatism. I end with a discussion on future challenges and research idea for bridging volcanology and geomorphology.

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Allocated presentation: Talk [Invited]

How to find volcanoes that no longer exist?

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Over the last decade, the connection between silicic volcanic and plutonic rocks is therefore of great interest and has received increased attention from the scientific community. Accepting such connection prompts further questions: (1) what should silicic cumulates look like? (2) Which plutons are indeed cumulates, and which plutons should be considered "failed eruptions"? (4) Do all magma reservoirs erupt, and if not, what percentage of them do (i.e. the volcanic-plutonic ratio)? (5) Has the volcanic-plutonic ratio changed through history? Studies on the distinction between silicic volcanics and plutonics are difficult for most systems, as when plutonic rocks are exposed in the Earth's surface, volcanics are often already eroded and no longer available. My presentation offers a solution to this problem by demonstrating how volcanic/plutonic quartz and zircon can be distinguished using Ti-thermometers in detrital sediments. Using Ti distributions in the detrital record allows for separation of volcanic, plutonic, and pegmatitic crystals of quartz and zircon in a given magmatic system – even when the volcanics have been completely eroded. This technique offers for the first time a possibility to find volcanoes that have been completely eroded, holding potential to further understand the growth and evolution the continental crust throughout Earth's history.