ID: 17

THE IMPACTS OF LULLS AND PEAKS IN ERUPTION RATE ON LAVA FLOW PROPAGATION: INSIGHTS FROM ANALOG EXPERIMENTS

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Variable eruption rates can complicate lava flow forecasts. We used PEG wax to investigate how a lull and a peak in eruption rate (Q) influence whether a flow will expand or thicken. We conducted 30 experiments in which we erupted dyed wax into a chilled bath on a flat slope. The experiments were divided into two conditions: lull (50-second decrease in Q) and peak (50-second increase in Q). For each experimental run, an initial 150 cm^3 of wax was erupted at a Q varying between 1–6 cm^3/s. After the initial injection of wax, Q was either halved (lull) or doubled (peak) for 50 seconds. Afterwards, an additional 150 cm^3 of wax was erupted at the initial 1–6 cm^3/s. We observed three common emplacement modes: *breakouts (surficial and marginal), inflation, and tubes*. Our results indicate: (1) during lulls in Q if the crust is strong, the flow will expand via limited and localized marginal breakouts and tubes; and the flow will thicken due to resurfacing and inflation. (2) If there is a lull and the crust is weak, the flow will expand via widespread marginal breakouts. (3) If there is a peak and the crust is strong, the flow will expand via marginal breakouts and the flow will thicken due to resurfacing and inflation. (4) If there is a peak and the crust is weak, the flow will expand via widespread marginal breakouts. These results have implications for process-based statistical modeling and reconstructing historical eruption conditions.

ID: 44

A direct look on a monogenetic cone internal structure: the case of Granillo Rojo (Santa Cruz – Galapagos).

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Monogenetic, basaltic, spatter cones can erupt in highly urbanized regions. These cones are characterized by an articulated internal structure related with a Strombolian or Hawaiian eruption. The internal structures are not always clear with past studies utilizing different techniques that are rarely visible to the naked eye. The Granillo Rojo spatter cone, located on the island of Santa Cruz in the Galapagos, is a unique case. Excavation to recover pyroclastic material for civil use reveals the core of the cone, allowing analysis of different feeding and sedimentary structures. This study consists of a physical and petrographic characterization of the products, including a geometric reconstruction of the cone feeding system. The horse-shoe shape of Granillo Rojo is characterized by stratified levels of red dominated, loose, vesiculated pyroclasts with variable sizes from ashes to bombs. It has two main non-coevals feeding dikes. At the top of the western flank there are multiple lava flows demonstrating the final eruptive phases. The pyroclasts are angular, with a compact morphology, low sphericity, and spherical vesicles. Petrographic analysis indicates the basalts are glass dominated with large plagioclase phenocrysts. Plagioclase make up a majority of the visible mineral grains, with some pyroxene and olivine found as well.. By studying the Granillo Rojo quarry, we directly observed the structures of the volcano, allowing us to understand the genesis of a monogenetic scoria cone generated by multiple phases with quasi-constant magma composition. Our results allow us to better understand how these volcanoes are generated and their impact on society.

ID: 65

Understanding multi-volcanism in the large composite volcano of Kirishima, Japan

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Kirishima volcano, located in southern Kyushu, is a prime example of a large composite volcano in Japan. Over the past 150 years, many eruptions have occurred at three different volcanoes, marking a unique geological activity in Japan. Furthermore, it has been established that more significant eruptions have produced around the past 4.5 thousand years across three volcanoes within Kirishima as the multi-volcanism (Tajima et al., 2013). A vast partial melting body, as large as the area of the volcano, extends under the 10 km depth, coexisting with a smaller seismic attenuation body found at depths of 4–5 km. During the 2010–2011 Shinmoedake eruptions, a complex interplay of volcanological events unfolded by many studies. A deep area of low-frequency earthquakes at depths of 20–27 km beneath the southeast end of Kirishima volcano became active. Inflation was observed at depths of 8–10 km beneath the northwest end, and magma mixing was detected at depths of 4–6 km beneath the center through extensive research efforts. Subsequently, another eruption occurred at Shinmoedake, from March 1 to June 27, 2018. Simultaneously, geothermal activity at Iouyama began intensifying early in 2018, culminating in a minor eruption on April 19. This synchronous activity suggests a potential connection to a shared shallow magma reservoir at depths of 4–5 km, as concluded by Tajima, et al. (2022). We have studied historical records for 1200 years and found that Kirishima volcano shifted to multi-volcanic activity in the 16th century.

ID: 112

Analysis of Magnetic Field Variations Compared to Seismic and Infrasound Activity at Chiles Volcano Using Sensor Arrays

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In this work, a monitoring system has been used to measure the variations in the magnetic field produced at the Chiles volcano, located in Ecuador and Colombia. Additionally, an array composed of twelve one-component sensors arranged in various geometric configurations has been implemented by detect seismic and infrasound signals.

The system refers to a compact and highly reliable prototype used in volcanic monitoring applications. It is composed of magneto-metric sensors and makes use of long-range wireless transmission technology known as LoRa (Long Range). Furthermore, it has a controller developed on an Arduino platform that has two serial communication interfaces. One is used to communicate with the magnetometer and GPS receiver, while the other interface communicates with the LoRa radio transmitter module. Lastly, as a complement to this magneto-metric system, a seismic station is used that has an embedded system that is responsible for the acquisition, digitization, and storage of seismic and infrasound signals captured by the array of twelve sensors.

The data collected from the variables under study, i.e., magnetic field variation and seismic signals, have been subjected to rigorous statistical correlation analysis. As a result of this analysis, we have identified several anomalies in the magnetic field in the geothermal zones of the aforementioned volcano, particularly in the month of July 2022, when seismic activity was at elevated levels. Consequently, this technical article provides a preliminary assessment that will serve as a basis for future quantification of the impact of magnetic fields on seismic activity in this volcanic complex.

ID: 114

Modelación Estocástica de Dependencia Geomorfológica en el Campo Volcánico Michoacán-Guanajuato, México, Utilizando Teoría de Cópulas

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El Campo Volcánico Michoacán-Guanajuato, ubicado en la Faja Volcánica Transmexicana, es considerado el campo monogenético más extenso del mundo con una gran variedad de estructuras volcánicas. Tras múltiples estudios, registros históricos y análisis geológicos, esta región sigue siendo compleja de estudiar aún con demasiada incertidumbre en su caracterización. Para abordarse, es conveniente aplicar modelos basados en la teoría de la probabilidad y estadística. Los modelos estocásticos, fundamentados en la teoría de cópulas, permiten identificar y determinar la dependencia entre variables, ajustando distribuciones a los datos y proponiendo modelos de dependencia. La teoría de cópulas ha demostrado su utilidad en diversos campos, como finanzas, industria petrolera, economía, entre otros.

En este estudio, nos enfocamos en analizar variables morfométricas en la región del sureste del campo mediante la aplicación de la teoría de copulas para modelar sus relaciones de dependencia.

La metodología propuesta consiste en un análisis univariado para obtener estadísticas descriptivas, el ajuste de funciones de densidad a cada variable y la construcción de funciones bivariadas paramétrica (Cópula de Frank) y no-paramétricas (Kernel Smoothing y Bernstein). Por último, se realizan las simulaciones de las variables y se comparan con los datos originales, evaluando la dependencia mediante coeficientes de correlación (Kendall, Spearman y Pearson). Este método es aplicado a tres tipos de estructuras volcánicas: Spatter, Domos y Conos. Se examinan los resultados obtenidos para justificar la introducción de las cópulas como una herramienta valiosa en los análisis vulcanológicos de campos volcánicos monogenéticos, ofreciendo una perspectiva novedosa para comprender la dependencia geomorfológica.

ID: 135

Amp-TB2 protocol, a thermobarometric model for constraining magma feeding systems of amphibole-bearing volcanoes: the example of Bezymianny volcano, Kamchatka

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Amphibole plays a crucial role in the study of several earth and planetary processes. One of its most common applications is thermobarometry for volcanic systems. Many amphibole thermobarometers require the melt composition which is not always available in volcanic products and/or show rather high errors for characterizing the pressure (P) and depth of crustal magma chambers. Amp-TB2, [1], presents the advantage of being a single-phase model with relatively low errors (P±12%, T±22°C logfO_2±0.3, H_2O_{melt}±14%) and is valid for most of the calcic amphiboles in equilibrium with calcalkaline or alkaline melts across a wide T-P range (up to 1130 °C and 2.2 GPa).

This study reports a protocol on the application of Amp-TB2 based on detailed electron microprobe analyses performed on homogeneous natural standards and amphibole crystals of Bezymianny volcanic products. The application of this protocol is facilitated by a new version of the model (Amp-TB2.1.xlsx) including an equation to identify heterogeneous domains (disequilibrium; not suitable for thermobarometric constraints) and homogenous (equilibrium) zones within amphibole crystals, which can be used to quantify the physico-chemical parameters of magmatic crystallization. The depth (and P) estimated by Amp-TB2.1 for Bezymianny volcano are compared to seismic tomography results. Amp-TB2.1 results show (1) that Bezymianny is characterized by a very dynamic feeding system where the magma is stored at shallow crustal levels before recent activity periods characterized by climatic events and (2) that the pre-eruptive depth of magma storage generally increases with the age of the investigated products.

[1] Ridolfi, F. (2021): *Minerals*, **11**, 324.

ID: 160

Magma plumbing system of Ioto volcano, Ogasawara, Japan: A petrological constraint

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We have given a petrological constraint on magma plumbing system of Ioto volcano, Ogasawara, Japan. Ioto is a post-caldera volcanic island belonging to the Izu-Bonin Arc and known for its extremely active volcanism. The volcanic activity of Ioto has been characterized by rapid crustal deformation and a number of occurrence of phreatic eruptions. In this situation a magmatic eruption was firstly observed on the Ioto on July 2022. This eruption occurred in shallow sea off the southern coast of the island and repeatedly emitted cox-tail jets, washing up pumice blocks to the coast. The petrological analyses on the pumice blocks reveal that the Ioto magma has trachytic composition with porphylitic texture. Applying geo-thermo-hygrometers for plagioclase-melt and clinopyroxene-melt equilibria, the temperature and water content of the magma just before eruption are estimated to 970 ± 30°C and 1.4 ± 1.2 wt.%, respectively. The water content gives the pressure of 23 ± 20 MPa from water solubility model. The depth of 1070 ± 930 m is calculated from the lithostatic pressure with crust density of 2200 kg/m^3. These values indicate that magma with temperature of 1000°C had risen to 1000 m below the surface before the eruption. On the other hand, VLP earthquakes indicate that the center of magma chamber is located 6000 m below the surface. These suggest that the magma plumbing system of Ioto volcano is developing from depth of several kilometers to the shallow part of the volcano, contributing to the active volcanism.

ID: 286

Hydrothermal outgassing dynamics revealed by coupled seismo-acoustic observations (Pisciarelli, Campi Flegrei Caldera, Italy)

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The hydrothermal outgassing at active calderas is the evidence of an efficient fluid transfer from the underlying system and it can be used to retrieve crucial information which can be useful for volcanic risk assessment. Nevertheless, the real-time measurement of gas fluxes remains a challenge for volcano monitoring.

The Pisciarelli hydrothermal field is a key area of the Campi Flegrei caldera (Italy), where the intense outgassing is associated with persistent seismic tremor, whose escalating amplitude trend over the last decade well correlates with the key geochemical parameters, indicating a pressurization of the underlying hydrothermal reservoir.

As part of the INGV LOVE-CF and INGV-DPC B2 Research Projects, we investigated the seismo-acoustic wavefield produced by hydrothermal outgassing to propose a potential tool to estimate gas fluxes in real-time. Data from a 4-element seismo-acoustic array were used to locate the tremor source at a shallow depth beneath the hydrothermal field. The tremor amplitude is mainly controlled by the fluctuations of the hydrothermal water level within the hydrothermal conduits. We also recognized two distinct acoustic sources associated with the intense water bubbling and the over-pressurized steam emissions from the hydrothermal vents.

Integration between acoustic and seismic observations allowed us to propose a potential mechanism for tremor generation through the volume reduction of steam bubbles while ascending.

These results have brought to a better understanding of the dynamics of hydrothermal outgassing at Campi Flegrei Caldera, which may bring to a real time estimation of hydrothermal gas fluxes, and then improving the real-time volcano monitoring capabilities.

ID: 310

Unveiling the secrets beneath Campi Flegrei: probing the depths with receiver function analysis

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We used receiver function (RF) analysis to study the crust and the upper mantle of Campi Flegrei (CF) up to 50 km depth. The CF volcanic system has a complex volcano-tectonic setting, which hosted numerous explosive volcanic eruptions during the Upper Pleistocene and Holocene. Monitoring of this volcano is crucial due to the high population density around it, also considering that the volcano has been showing, since decades ago, signs of unrest with episodes of ground deformation, degasification, and seismicity. Therefore, studying RF also contributes to a better understanding the ongoing dynamics.

Firstly, we obtained the RF from ten stations using multiple-taper correlation deconvolution. Then, we applied the transdimensional approach of Bodin et al. (2012) to determine 1D profiles of P and S-wave velocities and the probability of discontinuities beneath each station. We also analyzed changes depending on the backazimuth. Finally, we interpolated 1D models to obtain a preliminary 3D model beneath CF.

The crust presents a thin, low-velocity layer related to shallow volcanic rocks. Below, we find a 6 km thick high-velocity layer, likely associated with thermometamorphic and igneous rocks. Below 8 km depth, we found two velocity anomalies, possibly indicating the presence of two or more prolate magma chambers with a total volume of about 200 km^3. In the upper mantle, we found a low-velocity zone with a thickness of about 7 km, possibly representing a zone of partial melting from which the magmas of CF originate. A similar feature has been also found in other active volcanoes.

ID: 341

Fantastic fissure eruptions and where to find them: Insights from an experimental study

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Eruptions like Kilauea (2018), Fagradalsfjall (2021), and La Palma (2021) are fed by dikes, that form elongated fissures, spanning hundreds to thousands of meters. While field, seismic, and geodetic data reveal the extensive lateral and vertical dimensions of dikes, fissure eruptions can rapidly become discontinuous and localize to discrete vents. Active vents may migrate, shut down, and reactivate during the initial eruption stages, adding complexity to hazard assessment and risk management. Thus, understanding the key factors governing fissure eruption dynamics is essential for forecasting the early evolution of future eruptions especially in populated areas that could potentially be affected.

We use an experimental setup of an artificial fissure to explore the thermal processes governing flow dynamics in fissures. In these experiments, we inject molten wax into a non-planar slot and monitor flow behavior with particle tracking and temperature measurements at the wax-wall interface. This setup offers flexibility in adjusting fissure width, geometry, wall temperature, and injection rate, with the ability to vary these parameters during a single experiment or keep them constant.

Within the first few minutes of an experiment, we observe flow diverting from narrow, colder sections of the fissure to wider, warmer segments. Additionally, wax flow responds dynamically to obstacles such as cavities and blockages leading to interesting flow patterns and feedback effects. These experiments combined with computational models and monitoring data, have the capability of being useful in assessing the predictability, or unpredictability, of fissure eruption evolution in early eruptive stages.

ID: 354

Magma storage and transport along volcanic rift zones constrained by geodetic data and dynamical models

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Surface deformation shows that mature rift-zone eruptions produce significant deformation of the encasing rocks. Thus, volcanic conduits act as secondary reservoirs where we expect their physical properties, such as geometry, have significant impact on eruptive dynamics. Here we develop a dynamical model in which the chamber is connected to the surface through a deformable conduit. The results show that magma overpressure increases the width of the conduit, resulting in a higher discharge rate than expected for the rigid case. At the same time, high aspect ratio conduits have larger compressibility that can sustain eruptions over longer timescales. The net effect is that rift zones can maintain high fluxes over prolonged periods of time, leading to large eruptions and biasing magma compressibility estimates.

We apply our model to the 2018 Kilauea eruption where episodic collapse of the summit led to pressure pulses that propagated down-rift and that were recorded by both tiltmeters and peaks in the effusion rates. Inversion of the data indicates a conduit with a height of 700-800 m and a maximum opening of 4 m, at a depth of 2.5 km in the Upper East Rift Zone, becoming shallower beneath the Pu’u ’O ’o region then propagating sub-horizontally to the Lower East Rift zone vents. Based on these properties we infer that up to 30% of the erupted volume was attributable to magma stored in the rift zone. In agreement with recent studies, we find that magma over-pressure was low at the end of the 2018 eruption.

ID: 357

The noble gas and carbon isotopic signature of the 2021 Tajogaite eruption (La Palma, Canary Islands)

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We characterize the temporal evolution of volatiles during the 2021 Tajogaite eruption at La Palma by analyzing the elemental and isotopic (He-Ar-Ne-CO2) composition of fluid inclusions (FI) in mafic phenocrysts separated from selected lavas. During the eruption, the volatiles concentrations and $^{40}Ar/^{36}Ar$ in FI as well as MgO, CaO/Al_2O_3, Ni and Cr abundances in bulk rocks increased since mid-October; this phenomenon is associated with the raise of more primitive, less-degassed magma from the deeper mantle. $^3He/^4He$ remained constant throughout the eruption at MORB-like values (7.38±0.22 Ra, 1s), suggesting an isotopically homogeneous magma feeding source. These values are like those observed for the 1677 San Antonio lavas (7.37±0.17Ra, 1s), but more radiogenic than the $^3He/^4He$ values (>9 Rc/Ra) observed in the Caldera de Taburiente. The homogeneous $^3He/^4He$ of Tajogaite/San Antonio lavas reflect three components mixing between a MORB-like, a radiogenic component and small additions of a high $^3He/^4He$ reservoir (>9Ra). The carbon isotopic ratio of CO_2 ($\delta^{13}C$) measured in Tajogaite/San Antonio lavas range from -4.94‰ to -2.71‰ with $CO_2/^3He$ ratios from 3.4 to 6.1×10^9. The $\delta^{13}C$ values fall within the range of previously reported values for the Dos Aguas cold spring (Taburiente Caldera), suggesting an apparent carbon isotope homogeneity of the entire island. The $\delta^{13}C$ variability can be interpreted as due to: open-system degassing process of a common mantle endmember having $\delta^{13}C$ of ~1.7 ‰, or mixing between depleted mantle-like carbon (-6‰<$\delta^{13}C$<-4‰) and crustal carbon ($\delta^{13}C$ = 0‰) endmembers. Both models testify a crustal carbon component recycled in the local mantle.

ID: 359

Assessment and optimisation of seismic network design to detect magma migration using SARA

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Volcanic eruptions are frequently preceded by magma migration towards the surface that trigger seismic swarms, that saturate the seismic signal, limiting the analysis techniques that can be effectively applied in real time crises. The Seismic Amplitude Ratio Analysis (SARA) provides a simple method to image the dynamics of seismic magma migration in real time.

We analyse how the location of the seismic networks can impose special constrains that limit the effectiveness of SARA. We introduce a method to quantify the detection capability of the seismic network for different magma migrations and analyse how the detection capability could be improved by changing the seismic stations locations. We use the seismic networks of more than 100 volcanoes, and calculate the potential to detect vertical, diagonal and inclined migrations below the volcano edifice. Also, we investigate the influence of vent-station proximity on magma conduit coverage, and identify the distance ratio that yields improved coverage

Furthermore, we perform a statistic analysis on the seismic networks locations and use the decision tree regression algorithm to identified key factors that contribute to the efficiency disparity among seismic networks coverage. Notably, our findings reveal that optimizing seismic network coverage entails maximizing both the standard deviation and median of relative pair station distances, all while maintaining a prescribed minimum separation distance between pairs. We believe our results provide valuable information for smart seismic network design, particularly useful in crisis response scenarios and regions with limited resources, where maximizing the coverage of available monitoring stations is crucial.

ID: 407

AVERT: An open system for multi-parameter volcano monitoring

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Streaming of multi-parameter instrumental data from active volcanoes remains a key challenge in the drive to develop the next generation of physics- and data-based eruption forecast models. Here we report on the development and field testing of a multi-parameter, real-time, open-data volcano monitoring system through our collaborative project AVERT: Anticipating Volcanic Eruptions in Real-Time.

The AVERT system incorporates a broad suite of traditional and novel instrumentation for volcano monitoring; power-efficient radio and satellite telemetry; and a low-power single-board computer at each site to manage data harvesting, telemetry, and preliminary in-situ analysis to optimize data bandwidth usage. The system's small form factor and modular design facilitates rapid deployment and straightforward extension to a wide variety of instrumentation. The design plans and software for remote and server-side management are openly available, as is the goal for the data itself. The first implementation of the system was deployed at Cleveland volcano in the remote Aleutian arc, Alaska in September 2022, in partnership with the Alaska Volcano Observatory. We will present an overview of the data and some initial analyses from the broad suite of instruments deployed at Cleveland. A follow-up deployment is planned for November 2023 at Poás volcano, Costa Rica, with partners from Observatorio Vulcanológico y Sismológico de Costa Rica (OVSICORI). This second deployment will complement the existing instrumentation at Poás and serve as a community testbed for real-time data gathering and telemetry during field workshop in February 2024.

ID: 428

A next generation chronology of Late Pleistocene to Holocene volcanism in the southern Andes

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Villarrica and Mocho-Choshuenco are two of the most hazardous composite volcanoes in the Andean Southern Volcanic Zone (SVZ). In order to constrain their effusive and eruptive records, we have undertaken a multi-chronometer approach involving $^{40}Ar/^{39}Ar$ dating of Late Pleistocene-Holocene lavas, ^{14}C dating of distal tephras, and ^{3}He surface exposure dating of several Holocene lavas and parasitic cones. Moreover, we have reevaluated old literature (1860 to 1960) to confirm or discard historic eruptions at these edifices. Our results include 48 new ages ($^{40}Ar/^{39}Ar$ (n=38), ^{3}He (n=8), ^{14}C (n=2)) from 350 to 0.5 ka.

Our age determinations reveal that cone growth at both volcanoes was quasi-continuous and more rapid than thought. Moreover, much larger portions of both volcanoes were built during the last 50 ka with effusive eruptions occurring despite thickening of the surrounding Patagonian Ice Sheet to nearly 2 km by 18 ka. At about 16 ka, caldera-forming explosive eruptions produced 8 km^3 of pyroclastic flows and falls of basaltic andesite at Villarrica and 5.3 km^3 of rhyolite at Mocho-Choshuenco. Explosive eruptions since 16 ka have produced another 10 km^3 of airfall tephra. ^{3}He surface exposure ages constrain Holocene lava flows erupting from 2.2±0.4 to 0.3±0.1 ka, some of which reached populated areas. Moreover, parasitic cones in both edifices erupted at 2.3±0.2, 1.0±0.1, and 0.5±0.1 ka.

The results indicate that these edifices are much more active and hazardous than previously thought. Moreover, these findings are critical to investigate the response of magma plumbing systems to regional external forces such as glaciation.

ID: 486

The evolution of a basaltic fissure eruption

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Basaltic eruptions produce lava flows that have the potential to destroy local infrastructure and emit toxic gas and particles that may adversely impact public health. Predicting their style and evolution is therefore a key goal in volcanology. This requires an understanding of the multiphase flow processes that operate within the sub-volcanic system.

Field observations of both solidified and erupting basaltic fissures at Kīlauea volcano (Hawaiʻi, USA) are synthesised with laboratory analogue experiments to determine the evolving organisation of gas-driven flow patterns within basaltic feeder dyke systems, and their effects on eruptions. Our laboratory kit was designed to perform scaled analogue experiments of bubbly flows in a 3.0 x 2.0 x 0.03 m glass-walled slot. This geometry mimics the geometry of dykes that feed most basaltic eruptions, whereas previous experimental studies have usually assumed a cylindrical conduit. The role that localization of fissure segments plays in shaping eruption behaviour is explored by occluding parts of the top of the slot. We also consider the role played by flooding of the vent with lava, focussing on long-lived systems that are reproduced by a conical vent geometry. We collate the imagery acquired during our analogue experiments with recent monitoring datasets and a detailed field investigation of the spatial organization of vents and drain-back structures on solidified fissures at Kīlauea to improve our understanding of the controls on the eruptive behaviour of basaltic systems. This study will help interpret the underlying flow patterns within feeder dykes from real-time gas and erupted lava flux measurements.

ID: 538

Evolution of plumbing system and eruptive style at Stromboli (Aeolian Islands -Italy) during the last 4 millennia

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Stromboli is known for its persistent activity and for the steadiness of its feeding system over the time. Rosi et al. (2000) in a single hand-dug trench recognised two distinct tephra successions separated by a paleosoil: the Upper Sequence (U-Seq), younger than 8th century CE, consisting of coarse ash deposits associated with discrete layers of lapilli fallout, and the Lower Sequence (L-Seq), containing cm to dm-thick lapilli beds, alternated with massive slightly reworked ash. U-Seq volcanics are produced by quasi-persistent mild explosions, periodically disrupted by more energetic paroxysms as those observed in the present-day activity. By contrast, the L-Seq volcanics are compatible with repeated episodes of lava fountains separated by periods of quiescence. These differences in the eruptive style are plausibly related to changes in composition of the feeding magma and to the geometry and dynamics of melts within the plumbing system. To track these processes, we extended tephrostratigraphic investigations to natural exposures or excavated trenches along the whole emerged part of the volcano. This study has produced new dating and the physical characterization of both U- and L-Seq deposits to deduce eruptive parameters. Petrology of the L-Seq volcanics provided insights on the plumbing system active before the 8th century CE and on its evolution back in times. Our findings highlight that L-Seq activity began more than 3 ka, being much older than previously thought. Moreover, L-Seq exhibits a compositional variability (Shoshonitic-HKCA series) much larger than that observed in U-Seq products.

ID: 568

The deep structure of the Campi Flegrei caldera by magnetotelluric survey

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Electromagnetic imaging can proficiently detect deep structures in volcanic environments. A magnetotelluric (MT) survey recently performed allowed to obtain a 3D tomography of the 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 survey involved about 50 measurement sites whose inversion produced a 3D resistivity imaging, which identified 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 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. The resistivity model allows (i) constraining the main electrical features and (ii) delineating major clues of the caldera's setting.

ID: 604

A rapid outpouring of lava from the Great Crack of Kīlauea volcano in 1823 CE: How did it happen?

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The 1823 CE Keaīwa lava flow in the Southwest Rift Zone of Kīlauea volcano is unique in its flow morphology and lack of constructive vent topography, despite having a similar composition to other lavas erupted at Kīlauea. This lava flow issued from a ~10 km-long open fissure known as the Great Crack, and it has an unusually thin sheet-like morphology with flow margin thicknesses of ~10–65 cm. Based on field relationships at the vent (e.g., drainback features), we propose that the Great Crack formed, or at least significantly widened, syn-eruptively during the 1823 CE eruption. The absence of pyroclastic or scoria cones indicates that the eruption consisted of a catastrophic outpouring of relatively degassed lava as the fissure unzipped. Moreover, the rapidly moving flow overcame pre-existing tumuli and scoria cones (Lava Plastered Cones) up to ~17 m tall. Glass and bulk-rock analyses show homogeneous compositions (6.4±0.1 wt. % MgO) along the Great Crack, yielding eruption temperatures of 1152±15°C. Keaīwa flow morphology is therefore not a direct consequence of unusual magmatic or rheological conditions, but rather high effusion rates associated with the sudden drainage of uprift magma through the fissure. Ongoing lava flow models using VolcFlow on a 2 m DEM show that minimum effusion rates of ~8000 m^3/s and flow velocities of ~10 m/s are required for the flow to overcome the pre-existing scoria cones. This study has allowed us to understand the possible hazards associated with the Great Crack eruption mechanism such as earthquakes and lack of forewarning.

ID: 644

Constraining the active structures during the recent unrests at Campi Flegrei caldera (southern Italy) through seismicity analysis and electromagnetic imaging

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Ground deformation is a remarkable feature of caldera systems and is often accompanied by shallow seismicity mainly related to pressure variations within the hydrothermal/geothermal system. Here, we analyzed the earthquake distribution during the two most recent unrests at Campi Flegrei caldera (Italy), which pose enormous concerns to millions of citizens. We analyzed the seismic events in the 1983-84 and 2005-2023 periods, during which the cumulative ground uplift exceeded 2 meters and was accompanied by over $11 x 10^3$ located earthquakes, mainly occurring within 3-4 km of depth. We compared the two periods, and although some similarities are recognizable, in the current unrest, the seismicity records the maximum density in the Solfatara area, whereas, in 1983-1984, the maximum frequency was spread out along a broader WNW-ESE elongated area in the central sector of the caldera. Subsequently, we investigated the relationship between the hypocentral distribution, defining several clusters, the electromagnetic imaging of the shallow crust, and the main faults recognized in the literature. Then, we used the focal mechanisms calculated for the two periods to estimate the stress fields for each cluster. The analysis of the whole catalogue suggests that a ca. N-S extension characterizes the central sector of the caldera, unlike the focal mechanisms in the Pozzuoli Gulf, where deeper earthquakes occur, denote a compressive stress field. In agreement with electromagnetic data, we suggest that earthquakes illuminate fluid paths along which new fractures form within the pre-existing fault zones, conveying fluids in the shallow hydrothermal system with potential repercussions for future hazard scenarios.

ID: 668

IDENTIFICACIÓN Y EVALUACIÓN DE ANALITOS LIXIVIABLES EN LA CENIZA EMITIDA POR EL VOLCÁN SABANCAYA, PERÚ

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El proceso eruptivo del Volcán Sabancaya-Perú inició en noviembre del 2016, presentando actividad explosiva con procesos formación y destrucción de domos de lava al interior del cráter, con emisiones de grandes cantidades de cenizas, cuyos lixiviados son de composición química desconocida, así como los efectos de los lixiviados sobre la población y ecosistema del valle del Colca, región Arequipa y su relación con los procesos eruptivos del volcán.

Se colectó cenizas en torno al volcán Sabancaya en septiembre del 2018 y abril de 2019. Las muestras se lixiviaron con agua desionizada, en proporciones 1:25 y 1:100, se analizaron por ICP-OES (Espectroscopia de emisión óptica de plasma acoplado inductivamente), ICP-MS (Espectrometría de Masas con Plasma Acoplado Inductivamente), cromatografía iónica y Titrimetría, identificándose 33 analitos.

En la granulometría de las muestras, se encontró que el 70 % de la ceniza está compuesta por granos mayores e iguales a 0,18 mm, las partículas más pequeñas ($<0,032$ mm) tienden a depositarse en los puntos más cercanos al cráter. Los mejores resultados se obtuvieron en la proporción 1:100, ya que en 1:25 se presentó saturación durante los análisis Los resultados muestran un mayor aporte de lixiviados en las muestras de septiembre del 2018 a comparación con las de abril del 2019, lo que interpretamos como el aporte de gases expulsados durante el ascenso de magma que dio origen al crecimiento acelerado del domo HUK, el cual al emplazarse y cubrir ampliamente el suelo del cráter redujo la emisión de gases.

ID: 744

Spectral analysis of Nevado del Ruiz Volcano seismicity preceding 2012 eruptions: Understanding volcanic processes and conduit properties variations.

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After Nevado del Ruiz Volcano (NRV) devastating eruption in 1985, its volcanic and seismic activity has had two significant increments, one of them in 2012, which resulted in two VEI 3 eruptions on May 29th and June 30th; and the last one, occurred from March to June 2023, raising the volcanic activity level from yellow to orange, we conducted an analysis of the spectral content for the volcano-tectonic (VT), low frequency (LF) and hybrid (HB) seismicity reported in NRV during 2012. The purpose was to evaluate the behaviour of the high to low frequency ratio prior to the eruptions of May and June 2012. The presence of visible variations in the spectral properties may suggest changes in the properties of the conduit and the dominant internal processes at each of the stages before the eruption. Any identifiable variation if the band ratio could have significant implications for seismic monitoring of NRV, specially as a seismicity reference pattern for eruption forecasting in upcoming events.

ID: 442

Una metodología para el estudio de variaciones temporales de la atenuación sísmica en el Volcán Nevado del Ruiz (Colombia) mediante el uso de señales sísmicas generadas en el nido sísmico de Bucaramanga.

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En este estudio se presenta una nueva metodología para evaluar la variación temporal de la atenuación de ondas sísmicas en el volcán Nevado del Ruiz (VNR), mediante el uso de sismos regionales provenientes del Nido sísmico de Bucaramanga (NSB) uno de los únicos tres nidos sísmicos del mundo, el cual está localizado a más de 500 km del volcán, y se comporta como un punto de fuente sísmica repetitiva, lo que permite hacer seguimiento a las variaciones temporales de la atenuación sísmica en la zona del VNR. Se pudo observar que existe una variación temporal de la atenuación sísmica en sectores del VNR que pueden estar asociados a cambios en la actividad volcánica probablemente debidos al movimiento de fluidos. En particular se detectó aumento de la atenuación entre 2017 y 2018 y posteriormente un nuevo aumento mayor entre 2021 y 2023, fechas en las que la actividad del volcán presentó un aumento importante. Estos cambios coinciden con variaciones en la desgasificación y movimiento de magma al interior del volcán detectados con otros instrumentos y técnicas, lo que sugiere que el uso de sismos lejanos repetitivos localizados en el nido de Bucaramanga sirven como una nueva herramienta de monitoreo sísmico volcánico en Colombia.

ID: 19

Paleoenvironmental Constraints on Pleistocene Ice Sheets Informed by Glacio-Volcanic Deposits in Northeast Iceland

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A growing body of research suggests that deglaciation can lead to increased eruption rates by destabilizing existing magma bodies and even prompting new magma generation. Iceland is the ideal locality on Earth to study volcano-ice interactions as much of its landscape is dominated by glacio-volcanic landforms. One product of magma-ice interactions is volcanic glass, which contains dissolved volatiles such as H_2O, CO_2, and SO_3. The pressure dependence of volatile solubility in magmas allows estimation of the ice thickness at the time of eruption by measuring the volatile content of glassy eruption products. Here, we use volatile estimates from samples of three tuyas (Gæsafjöll, Bláfjall, and Búrfell) to test the hypothesis that in northeastern Iceland the Pleistocene ice sheets thickened southwards towards the present-day location of Vatnajökull ice cap. Major element and sulfur concentrations of the glasses were analyzed by electron microprobe (EPMA) at the University of Wisconsin-Madison, and major element concentrations are basaltic for all three tuyas. Gæsfjöll and Bláfjall have similar major element concentrations, whereas Búrfell is relatively enriched in FeO and depleted in MgO and CaO. Glass (n=102) SO_3 contents, which are proxies for water, range between 100 ppm and 3,100 ppm for all three edifices with SO_3 contents generally increasing towards the south (Gæsafjöll=199.1 ppm–1,864.9 ppm; Bláfjall=130.4 ppm–2,356.3 ppm; Búrfell=163.3 ppm–3,001.8 ppm). Thus, our preliminary data support the idea that the Pleistocene ice bodies through which these three volcanoes erupted thickened to the south. Future work includes FT-IR measurements of H_2O and CO_2 to further test this hypothesis.

ID: 34

Preliminary textural and petrological insights from the recent eruptive products of Fuego and Pacaya volcanoes, Guatemala

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Magmatic water content influences the physical and chemical properties of silicate melts, and is consequently a key control on the timing and pressure of vapour saturation, alongside the conditions under which magmas and co-existing fluids are stored in the crust. To investigate the relationship between primary water content ($H_2O_{(o)}$) in magmas and the partitioning behaviour of trace elements, we selected two contrasting yet closely-located volcanoes based on compiled literature $H_2O_{(o)}$ data from melt inclusions. Although Fuego and Pacaya are separated along the same segment of the Central American Volcanic Arc by only ~30 km, they exhibit high and low maximum $H_2O_{(o)}$ relative to typical arc values, respectively.

Preliminary work characterising the texture and geochemistry of bombs erupted during Strombolian activity at Pacaya in February and November 2017 (n=12) shows consistent phase volumetric proportions between the eruptive periods, with aggregated means of 39.4% plagioclase, 3.6% olivine, 0.9% augite, 0.3% titanomagnetite, and 54.8% glassy groundmass. Phenocrysts exhibit normal (olivine and plagioclase) and oscillatory (plagioclase only) zoning over a range of crystal sizes; reverse zoning is less common. EDS data estimate that plagioclase and olivine compositions span An_{55-80} and Fo_{60-80}.

Future work will involve preparing melt inclusions from both volcanoes for Raman spectroscopy, SIMS, and LA-ICP-MS, to constrain volatile and trace element evolution throughout the crystallisation interval. Trace element systematics in erupted tephra will be compared with aerosol compositions in the outgassed plume to determine element volatilities, and linked via petrological and thermodynamic modelling to track partitioning behaviour during magma storage and ascent.

ID: 133

“DETECCIÓN DE ASCENSO DE MAGMA Y EVOLUCIÓN DEL PROCESO ERUPTIVO DEL VOLCÁN UBINAS 2023”

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Ubinas, el volcán más activo del Perú, en febrero presentó un incremento en los sismos por fracturamiento, anunciando una posible intrusión de magma. Posteriormente, registró sismos híbridos y tremor armónico confirmando el ascenso de magma a zonas superficiales. El 22 de junio ocurrió la primera emisión de ceniza, alcanzando los 3500msnc, marcando el inicio del proceso eruptivo. El 04 de julio, comenzó la etapa explosiva, la misma que se prolongó hasta fines de agosto.

Se observó que previo a las explosiones, la actividad tremórica asociada a emisiones de ceniza disminuía, al mismo tiempo que se registraban VT´s (magnitud máxima: 2.7) localizados al NO del volcán e iban migrando hacia el cráter, haciéndose cada vez más superficiales. Al cabo de unas horas ocurría la explosión, expulsando gran cantidad de ceniza acompañada de balísticos. Este mecanismo podemos separarlo en 4 etapas:

Etapa I: Intrusión de magma. Migración de magma desde zonas profundas.

Etapa II: Sobre-presurización. El magma que ascendió hacia la superficie se solidifica formando un tapón. Causando una obstrucción del conducto, ejerciendo presión.

Etapa III: Movimiento/Ascenso de fluidos. Ascenso de fluidos/volátiles aumentando la presión interna.

Etapa IV: Fase explosiva, el tapón que obstruye el conducto, fue vencido por la presión ejercida por los fluidos/volátiles, liberándose de manera abrupta esa energía, produciéndose la explosión, con emisión de ceniza acompañado balísticos.

El seguimiento de la evolución del actual proceso eruptivo en base a la sismicidad y otros parámetros de monitoreo ha permitido la identificación de diferentes procesos geológicos ocurridos en el volcán Ubinas.

ID: 187

Compositional heterogeneities in minerals provide insights in the evolution of the volcanic plumbing system of the 2021 Tajogaite eruption, La Palma, Spain

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Volcanic plumbing systems beneath active volcanoes display the foundation of volcanic eruptions and define the essential part of the volcano's activity and origin. In the case of this work, the 2021 Tajogaite eruption of the Cumbre Vieja (La Palma, Spain) is petrologically characterised as the eruption brings the advantage of comprehensive monitoring prior to, during and after the eruption. Using the mineral chemistry of clinopyroxene and olivine supports deciphering the nature and evolution of the volcanic plumbing system. Compositional heterogeneities inside clinopyroxene (in Mg, Fe, Al, Na, Ti) and olivine (in Mg, Fe, Ca, Mn) crystals illustrate the origin of at least three compositionally different magmatic environments (MEs). The MEs are characterised by different mineral compositions (reflected by changing Mg# or Fo): MEI (Mg#74-81), MEII (Mg#69-73), MEIII (Mg#60-68) for clinopyroxene and MEA (Fo84-85), MEB (Fo82-83), MEC (Fo76-81) for olivine. A variation in zoning pattern from clinopyroxene and olivine crystals fingerprints several magma routes, transferring the crystal from one ME to another. The systematic characterisation of the magmatic environments relations suggests the recharge of the volcanic plumbing system by mafic magma (basanites, associated with MEI clinopyroxene and MEA olivine composition) into a more evolved magma system (tephrites, associated MEIII clinopyroxene and MEC olivine composition). Diffusion modelling determines timescales for the coexistence time of ME1 and ME2 prior to the eruption in weeks to months. This work applies the illustrated method for characterising the volcanic plumbing system accounting for the Tajogaite eruption of the Cumbre Vieja volcano.

ID: 190

2D numerical simulation of the shallow magmatic body at Krafla

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The Krafla caldera, located in the Northern Volcanic Zone of Iceland has become the most studied volcano in the country since its last eruption, the Krafla Fires, happened between 1975 and 1984. An extensive monitoring system has been developed, focused on both geothermal exploration and production, as well as scientific research. In 2009, the IDDP-1 drilling aiming to 4 km depth in search of supercritical hydrothermal fluids got stuck at 2.1 km, retrieving quenched glass cuttings. It was then understood that an unexpected and undetected rhyolitic magma body had been drilled. This body stood without apparent signs of crystallization 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 aim to simulate the dynamics of this magma. We perform 2D numerical simulations of the magma thermo-fluid dynamics, assuming thermodynamic equilibrium in a sill-like, disk-shaped body 1200 metres wide and 260 metres deep.
In order to simulate the magma dynamics we use the software GALES (Garg and Papale, Frontiers in Earth Sciences 2022), which solves the 4D dynamics of multi-component fluids in geometrically complex domains. 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 phase composition. The 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.

ID: 197

Transient gas emission during sintering and vesiculation of pyroclasts in volcanic conduits

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Gas monitoring is essential to understand eruption dynamics and associated hazards as shifts in composition are often interpreted as changes in the magmatic input or degassing depth. At open-vent volcanoes, fractures provide pathways for gas escape. Our observations at the Mono-Inyo Craters, USA, (as observed at other recent lava domes) show that conduits are commonly infilled by variously vesiculated pyroclasts with different shapes and sizes. So, we assess the evolution of such vesiculating and sintering fragmental systems to help us reassess volcanic gas emissions. Our experiments show that the competition between vesiculation and diffusive outgassing induces volume change of individual clasts that hamper sinter timescales, thus influencing the development of magmatic plugs. We show that polydisperse particulate systems can further impact both the competition between vesiculation and diffusive outgassing, and their impact on sintering, and thus volatile transfer through the system.

We posit that pyroclasts trapped in conduits can influence the volatile ratios monitored during gas emission, since: 1) shallow pyroclasts diffusively outgas at a certain rate, whilst 2) the fragmental system acts as a filter for the percolation of deeper exsolved volatiles. The ratio of shallow to deeper volatiles must reflect a) diffuse outgassing at shallow depth (controlled by the boundary conditions and fragment shape), and b) the development of intergranular permeability (controlled by the volumetric and rheological evolution of pyroclasts and their impact on sintering). We will discuss how the vesiculation/sintering-driven clogging of shallow systems has the potential to affect volatile ratio evolution from monitored gas emissions.

ID: 228

Probabilistic hazard analysis of active volcanoes based on energy partition

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Assessing volcanic hazards requires a thorough comprehension of volcanic behavior and the implications of eruptive phenomena. Historically, the analysis of uncertainties related to the future eruptions has relied heavily on the study of previous events. This information is sourced from a combination of geological records, historical documentation, and geophysical monitoring. Nonetheless, the heterogeneous nature of this data introduces disparities, both in attributes and chronological completeness. Broad VEI ranges can occasionally misalign with the actual characteristics of an effusive or paroxysmal eruption, especially concerning volumes and column heights, potentially leading to inaccurate interpretations.

This study introduces a fresh approach to volcanic hazard assessment by introducing the use of Energy Probability Density Functions (EPDFs). The methodological framework integrates a variety of datasets, such as GVP and LaMEVE, supported also by a comprehensive literature review. Primarily, it examines effusive volcanic phenomena in the Canary Islands within the paroxysmal activities of Mount Etna. In cases where data for specific volcanoes is absent or lacking, the model recommends employing EPDFs from volcanological analogous entities. By segmenting energy parameters into classifications based on lava and pyroclastic volumes, our approach aims to offer an innovative perspective on volcanic activities and their associated hazards, viewing volcanoes as energy systems

ID: 318

The current state of Tenerife (Canary Islands): a geophysical insight.

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In 2016, the volcanic system of Tenerife started showing geophysical and geochemical anomalies. Since then, INVOLCAN has undertaken a strengthening of the surveillance program to track the ongoing changes which are occurring within the volcano.

The deployment of a broadband seismic network lowered the completeness magnitude. This evidenced the appearance of seismic swarms of VT and LP events. We show the temporal evolution of the seismicity pattern and the b-value. Furthermore, using seismic interferometry, we show that the volcano is experiencing significant changes in the seismic velocities in the last year.

Apart from seismology, we conduct regular gravity and spontaneous surveys on the island. The gravity surveys are realized along a network of 58 points covering the whole island and have a bimestrial periodicity. Until now, the observed variations have been limited within the range of uncertainty of a few µGal. We also carry out spontaneous potential surveys with a monthly periodicity on a set of 38 points within the crater of Teide, the most prominent stratovolcano on the island. These measures complement the regular geochemical surveys measuring the CO_2 and H_2S efflux and the temperature gradient.

All these measurements indicate significant pressurization of the hydrothermal system of the island because of the injection of fluid of magmatic origin at depth. The absence of relevant ground deformations excludes the ascent of magma at shallow depth and, therefore, a short-term increase in the eruption probability. However, the continued increase of this hydrothermal unrest requires a further improvement of the monitoring program.

ID: 335

Crustal structure beneath San Miguel volcano, El Salvador, estimated from ambient noise recordings

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San Miguel volcano is one of the most active volcanoes in El Salvador. Our comprehension of its underlying structure still needs to be completed, and establishing a one-dimensional seismic velocity structure model is required to determine the source location of volcanic earthquakes. We collected ambient noise data from February 2014 to April 2014 using four broadband seismometers. We applied the Spatial Autocorrelation (SPAC) method and seismic interferometry to estimate the phase and group velocities of Rayleigh waves. Rayleigh wave phase velocities were calculated in the range of 0.2 to 0.4 Hz from the SPAC coefficients, while phase velocities exceeding 0.4 Hz were determined using zero-crossing frequencies (Ekstrom et al., 2009). In addition, Rayleigh-wave group velocities were estimated with seismic interferometry, which exploits Green's function from the cross-correlation of ambient noise recordings. Combining the results from both techniques gave a comprehensive insight into the seismic velocity structure from near-surface to upper crustal levels. The resulting dispersion curve encompassed a frequency range of 0.2 to 1.3 Hz, including fundamental mode phase and group velocities. Subsequently, a joint inversion approach (Hayashida et al., 2019) revealed a seismic velocity structure comprising four sedimentary layers, characterized by shear wave velocities ranging from 1.0 to 2.8 km/s. This velocity model facilitated the precise location of 15 volcano-tectonic earthquakes, coinciding with a deformation zone recognized as the San Miguel Zone Fault on the northern flank of the highly active San Miguel volcano.

ID: 346

Post-eruption volcano-ice interactions at Mount St. Helens: Application of multidisciplinary approaches to unravel changes in volcanic heat output

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The crater of Mount St. Helens is a unique natural laboratory to study volcano-ice interactions. Crater Glacier, which started forming after the 1980 eruption, is one of the world's last expanding glaciers and provides a remarkable opportunity to characterize the expansion of a glacier in an area of significant thermal flux. Although the new (2004-2008) lava dome is gradually cooling, present thermal and physical interactions with the encircling glacier are considerable. We provide a comprehensive overview of post-eruption volcano-ice interactions in the volcanic crater and present results from multidisciplinary on-site investigations performed over the last decade. These include repeated mapping of subglacial cave systems, climatologic measurements, attempts to characterize CO_2-fluxes, and petrologic analysis of tephra samples. We also make use of different remote sensing data to understand the development of volcano-ice interactions and related changes in heat output at Mount St. Helens. Investigating volcano-ice interactions may be an important monitoring tool as these interactions provide insight to the evolution of a volcanic edifice and may be an indicator for renewed volcanic activity.

ID: 362

Fluids migration and earthquakes at Campi Flegrei caldera: interpretation of the ongoing unrest from gravity and seismic data

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Since 2005 Campi Flegrei caldera is experiencing a renewal phase of unrest. Such unrest is characterized by ground uplift at rates exceeding 15 cm/yr, escalating seismicity, and temporal variations of fluxes and geochemical composition of gases. The cause of the unrest is thought to be a pressure source located at ~3 km depth, fed by a degassing magmatic body located below 8 km, and slowly heating the shallow aquifers, which constitute the hydrothermal system. During 18 years of unrest, episodic sudden increase of the inflation rate frequently associated with intensified seismicity in form of seismic swarms were observed. These episodes were interpreted as due to temporal increase of the mass flux of fluids from the deep degassing source.

The increase of mass is also expected to cause gravity variations, which should be observed by the relative gravity surveys periodically conducted in more than 30 benchmarks by the INGV-Osservatorio Vesuviano, in the frame of the monitoring activities.

Through the analysis of time-lapse gravity observations combined with relocated earthquakes, we focus on the episodes of increased ground uplift rate to better characterize the fluids' migration associated with the uplift. In particular, we aim to investigate whether the earthquakes' swarms are associated or not with mass variations, thus providing hints on the mechanisms of fluids rising. The results are relevant for assessing the volcano dynamics and the relation between seismicity and fluids' rising and release.

ID: 392

Investigating the relationship between deep long period earthquakes and volatile saturation depth and exsolution in the Alaska-Aleutian Subduction zone using geophysical and geochemical data

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Deep long period earthquakes (DLPs, 0.5 to 3 Hz peak frequencies) are observed beneath volcanoes in a variety of tectonic settings. They are typically defined as long period earthquakes (LPs) at >10 km depth, although 10 km depth is an arbitrary boundary established to distinguish between shallow and deep LPs. DLPs are observed during periods of unrest, eruption, and background activity and in dormant systems. They have P- and S-waves and in Alaska are located near volcanic tectonic earthquakes, suggesting their long period frequency content is not a path effect. DLPs may provide insight into the deep magmatic plumbing system and transport processes of magma and fluids, yet the source process remains elusive. We hypothesize that onset of volatile exsolution may limit the depths where DLPs occur in subduction zones. The robust seismic catalog and extensive geochemical sampling along the Alaska-Aleutians Arc offers a unique opportunity to test our hypothesis. We use geophysical data including the Alaska Volcano Observatory seismic catalog (1989-2021) and published storage depth estimates. Our geochemical analysis includes calculating the volatile saturation depth using MagmaSat with constraints from melt inclusion (MI) H2O and CO2 concentrations, whole rock CO2/Nb ratios, average CO2 flux measurements, and CO2/S ratios from high temperature fumaroles and remote sensing observations. 23 volcanic centers have DLPs of which 10 have MI data, 6 have CO2 estimates for primitive magmas, and 14 have storage depth estimates. We aim to further interrogate our data compilation to explore the role of subduction rate and sediment flux.

ID: 398

Architecture of the Three Sisters magmatic system imaged from gravity data

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The Three Sisters volcanic complex in the central Oregon Cascades has been experiencing an episode of volcanic unrest for more than two decades. An area centered ~5 km west of the South Sister volcano summit has been uplifting with variable rates since 1996 as measured with leveling, GPS, and InSAR. First the uplift rate increased rapidly, peaking at ~30-40 mm/yr in 1999, and then decreased exponentially until a recent acceleration measured in 2021. Over three different gravity surveys in 2019, 2022, and 2023, using a Scintrex CG-6 relative gravimeter, we measured relative gravity at 173 distinct sites across the Three Sisters volcanic complex. The position and elevation of each gravity site was measured using GPS. After correcting for tilt, internal temperature, Earth tides, and daily drift, we estimate and remove the regional gravity field to calculate the residual Bouguer gravity anomaly for a range of reference crustal density values. To interpret the resulting gravity anomalies in terms of subsurface density contrast we invert the residual Bouguer anomaly and use constraints from petrology on the expected magma composition, volatiles and crystal contents for different pressure and temperature conditions. We present preliminary models of the 3D crustal density distribution under Three Sisters. These results will provide insights on the source processes driving the recent volcanic unrest and the dynamics of the magma system during the eruptive flare-up at Middle and South Sisters that began ~50,000 years ago.

ID: 444

Estudio aeromagnético en el área del volcán Pelado, campo mono genético activo, Chichinautzin México.

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Los campos volcánicos monogenéticos son regiones que se caracterizan por presentar gran número de volcanes, generalmente pequeños, con la particularidad de poder surgir nuevos aparatos volcánicos, asociados a los controles estructurales de la zona.

Este trabajo multidisciplinario profundiza en la exploración y caracterización estructural del Volcán Pelado, uno de los volcanes más jóvenes que presenta el campo volcánico monogenético Chichinautzin. Mediante el análisis y procesamiento detallado de la información aeromagnética incluyendo filtros previamente diseñados para resaltar características y correlación con la información geológica de la zona, para presentar nuevos resultados del control estructural presente.

El volcán Pelado se encuentra ubicado en la cercanía del volcán Xitle (alrededor de 10Km), muy recordado por el tremendo episodio volcánico que devasto el centro ceremonial de Cuicuilco y cubrió un área de gran extensión en el sur de la cuenca de México. Aunque se han realizado buena cantidad de estudios geológicos, falta mucho que investigar y los estudios geofísicos, en correlación con los geológicos, permitirán estudiar su estructura e identificar rasgos, controles tectónicos y anomalías que pudiesen identificar los sistemas de alimentación del aparato volcánico.

Los resultados revelan la presencia de anomalías magnéticas significativas, producto de un sistema de estructuras, a diferentes profundidades, indicando la existencia de un control estructural que propició, los alineamientos de conos de escoria.

ID: 482

What mechanisms control transitions in explosive-effusive eruptions for pantellerite volcanoes?

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Pantellerites are a type of rhyolite characterised by anomalously low viscosity melts due to their excess alkali content. Despite their low viscosity, pantellerite volcanic centres are known to produce significant caldera-forming Plinian eruptions. Deposits commonly show continuous transitions between clearly explosive and apparently effusive eruptions, including signs of hybrid episodes. Where there are deposits in the form of lava-like obsidian, there is evidence that these are welded deposits with a clastogenic- or spatter-fed origin. Although factors such as bulk composition or volatile content have been investigated, the exact mechanism/s that control changes in eruptive style remain unclear. This evidence suggests that poorly understood, active pantellerite volcanoes (including those found in Ethiopia and Italy) could switch unpredictably in eruption style, representing a significant hazard in case of future unrest. Here, we present research from Tūhua (Mayor Island) in New Zealand, where the stratigraphy is well-constrained. An array of pumice (explosive) and obsidian (apparently effusive) samples were collected within complex eruption sequences to explore the variety of eruption styles and their underlying mechanisms. Using experiments and analysis of natural samples we test the hypothesis that variations in the abundance of microlites and nanolites controls explosivity through their influence on bubble nucleation and melt rheology. Furthermore, we consider the possibility that apparently effusive deposits on Tūhua may be welded units with a pyroclastic origin. If lava deposits are produced by welding, this may provide a viable explanation for apparent changes in eruption styles as it does not require changes in bulk magma compositions.

ID: 487

Determinación de la escala vertical en vídeos de erupciones volcánicas a partir del movimiento de clastos

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La videografía es una herramienta popular para el monitoreo y la caracterización de las erupciones volcánicas. Los vídeos de actividad moderadamente explosiva nos permiten inferir parámetros de la erupción como: la altura de las fuentes de lava, la velocidad de salida y la duración y frecuencia de los pulsos. Éstas pueden informarnos sobre los procesos subsuperficiales que operan en la estructura interna de los volcanes. Sin embargo, la forma y el tamaño evolutivos de los rasgos naturales que rodean a las fuentes eruptivas dificultan la conversión de píxeles a metros a partir de una imagen debido a la falta de puntos de referencia fijos con los que comparar las dimensiones. Presentamos aquí un nuevo método para determinar la escala vertical de estos vídeos. Medimos la posición vertical en píxeles de los clastos cerca de su cenit, sobre fotogramas sucesivos, y la convertimos en una aceleración. Suponiendo que la única fuerza que actúa sobre los clastos individuales cerca de su cenit es la gravedad, utilizamos el movimiento de los clastos para determinar la escala, convirtiendo píxeles en metros. Validamos este método con experimentos de laboratorio análogos y observaciones de campo de la erupción de septiembre de 2023 en Kīlauea (Hawaiʻi, EE.UU.). Este enfoque será útil para los vulcanólogos físicos que monitorean la dinámica de productos volcánicos como fuentes y/o balísticos a partir de vídeos disponibles tomados por equipos científicos, y comunidad en general (turistas y locales).

ID: 492

The ties that bind: Using geochemistry, morphology and scoria cone distribution to untangle the Karthala-La Grille plumbing system(s), Grande Comore

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Grande Comore is defined by two basaltic shield volcanoes: the larger Karthala volcano in the south and the smaller La Grille volcano in the north. Despite their proximity, the two volcanoes are distinct in their composition and morphology. Notably, La Grille lavas host mantle xenoliths that reveal metasomatic events in the mantle, whereas Karthala lavas show no evidence of any major input from a metasomatized source. Pronounced differences in SiO_2, K, Nb, Rb, and Zr highlight their separate sources, while the phenocryst-rich rock types ankaramite, oceanite, and plagioclase-phyric basalt, which are present at Karthala but not at La Grille, indicate their different transport and storage mechanisms. Furthermore, distinct scoria cone volume variations between Karthala and La Grille hint at a geochemical control on the volume of the scoria cones which echoes the eruptive phenomenology. Despite these differences, the transition zone between Karthala and La Grille remains poorly constrained. In this zone, the most recent eruptive deposits of La Grille coexist with the more recent deposits attributed to Karthala. The distribution and morphology of the scoria cones in this area are the visible manifestations of the underlying plumbing system. As a result, combining cone morphology with major and trace elements, Sr-Nd isotopes, and the melt inclusions of olivines from the youngest scoria cones near the suspected Karthala/La Grille boundary can help determine whether the two volcanoes share a plumbing system, have separate plumbing systems that interact at shallow levels, or have separate plumbing systems that do not interact.

ID: 557

Magnetotelluric survey for the Pantelleria Island geothermal exploration

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The island of Pantelleria represents an attractive target area for geothermal energy exploiting, due to the main characteristics of its geothermal system, such as high-temperature gradients (>150°C/km, as detected from deep wells measurement), hot fluids, and CO2 discharges on the surface, and active resurgence volcanism in the past, and the island has already been the subject of several studies aimed to assess its geothermal potential. To further increase the knowledge about the physical properties of the main structures of the geothermal system, a new magnetotelluric survey has been performed, which relies on the inversion of data collected in 80 independent soundings covering the whole area of Pantelleria. Through this survey, a 3D model of the electrical resistivity has been retrieved, highlighting the structures of Pantelleria down to a depth of 3 km b.s.l.

The electrical resistivity imaging is an optimal indicator of the subsurface discontinuities, both related to the presence of lithological discontinuities or differences in fluids permeating the rocks. These features are essential tools in geothermal exploration and allow deducing the properties of rocks and fluids and the existence and geometry of reservoirs and permeability paths.

ID: 566

Seismic Frequency Index (FI) to assess periods of unrest in San Miguel volcano using REDPy

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El Volcán San Miguel (VSM) is a persistently restless stratovolcano with approximately 30 identified eruptions since 1800. Since the eruption on December 29, 2013 (Volcanic Explosivity Index, VEI ≈ 3), none of the eight subsequent eruptive episodes have exceeded VEI 1. Owing to frequent degassing and an active hydrothermal system, the seismic monitoring network at VSM regularly records hundreds of earthquakes per day. In order to track seismic activity in real-time, El Salvador's Observatory at the Ministry of Environment and Natural Resources (MARN) uses the Repeating Earthquake Detector in Python (REDPy) to calculate statistics about earthquakes and group them into families based on waveform similarity. In particular, we find that changes in Frequency Index (FI)—a measure of earthquake frequency content—are the most reliable indicator of VSM's changing state. During the most recent eruptive episode—which began on November 15, 2022 and included at least 194 small explosions—we observed significant changes in FI in the weeks prior to the initial onset of explosions. Retroactive analysis of seismic data has identified similar FI changes during unrest periods in 2014 and 2016. We interpret changes in earthquake families and frequency content to be due to variations in the opening and sealing of degassing pathways under the volcano. We discuss how our long-term and real-time applications of REDPy help inform our decisions before and during volcanic crises.

ID: 583

Transferring Machine Learning Models to New Systems via Incremental Learning

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Real-time monitoring of volcano-seismic signals and identifying volcanic events is a complex task. It is essential to understand the activity of volcanos. Volcanic observatories often perform this monitoring by using supervised models that have been trained on large seismic catalogs. While these models achieve high accuracy rates on the data contained within the seismic catalogs, there are potential issues with this method.

First, producing the seismic catalogue is an expensive process. Second, the performance of models trained using the catalogue may decline over time as the dynamics of the volcano change. It is not necessarily a straightforward process to transfer models to new volcanos due to potential changes in the: source of events; type of events; station locations relative to the events.

This work alleviates these issues by building machine learning models that are able to adapt to new volcanic systems. These models based on incremental learning can automatically identify changes in the types of seismic events that are being detected. This study creates a pipeline used to train a model on a labelled seismic catalogue for Deception Island and transfers the model to an unlabelled seismic database from Colima volcano. There are large differences between these two datasets. The Colima database contains a wider range of event types that occur in a different volcanic area. The model can identify occurrences of new event types and recognise known events for the previously unseen volcanic dataset.

ID: 602

Magmatic hydrothermal fluid dynamics and surface emissions at Active volcanoes: A geochemical and geophysical multidisciplinary research

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Volcano hydrothermal systems are essential sources of energy and minerals, but they can also pose a hazard to human life and infrastructure. Understanding the processes that control volcano hydrothermal fluids' composition and evolution is vital to managing these systems better.

Multidisciplinary investigations, including geochemistry, geophysics, and structural geology, are essential for unraveling the structure and dynamics of active volcanic systems. Geochemical analysis of hydrothermal fluids provides information on the composition and evolution of the system, while geophysical methods can be used to image the subsurface structure and dynamics of the system. Structural geology provides insights into the plumbing system that controls the flow of fluids and gases within the system.

This presentation will discuss the importance of multidisciplinary investigations for understanding volcano hydrothermal systems and present the early stage of a new research project that will be conducted in two Chilean volcanoes, Alitar and Olca. The project will combine geochemical analysis of gas and thermal water with CO_2 soil diffuse degassing and soil temperature with geophysical data using Transient Electromagnetic Current (TEM) to create a comprehensive model of the hydrothermal system.

This project is expected to provide new insights into the structure and dynamics of active volcanic systems and contribute to developing better management strategies for these systems.

ID: 749

Descifrando precursores de muy corto plazo en un volcán activo con lago cratérico hiperácido y caliente: Caso de estudio en el volcán Rincón de la Vieja, Costa Rica

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Rincón de la Vieja es un estratovolcán complejo ubicado en la región norte de Costa Rica. Caracterizado por frecuentes erupciones freáticas, freatomagmáticas o magmáticas en tiempos históricos. Es además uno de los 30 volcanes en el mundo con un lago hiperácido caliente que puede ocasionar el descenso de lahares por sus flancos luego de erupciones energéticas. El más reciente periodo eruptivo comenzó en el 2011 y continua en el presente. Un patrón común observada en las señales sísmicas, es la ocurrencia de una señal de baja frecuencia previa minutos antes de una erupción. Estudiamos las características sísmicas en el dominio del tiempo y la frecuencia de esta señal precursora y su relación con la energía sónica de las erupciones durante el 2023 a partir de una red de estaciones sísmicas e infrasonido alrededor del volcán, complementada con la información de 20 nodos sísmicos instalados desde la base a la cima del volcán, con un distanciamiento de 600 m aproximadamente para comprender la fuente de generación de esta señal y su interacción con el sistema magmático-hidrotermal. Comprender estos patrones sísmicos y su papel en la dinámica eruptiva son favorables en las mejoras de los sistemas de alerta temprana en caso del descenso de lahares y/o posibles flujos piroclásticos.