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Editorial: Challenges in seismology to our understanding of volcanic islands and their magmatic unrest

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Editorial on the Research Topic
Challenges in seismology to our understanding of volcanic islands and their magmatic unrest

Volcanic islands are some of the most intriguing geological features on Earth, yet the processes that lead to their formation and evolution remain largely enigmatic. Such islands exhibit complex, heterogeneous and anisotropic subsurface structures, characterized by pronounced and abrupt changes in seismic velocities, attenuation, anisotropy, and interfaces. Volcanic islands are amongst the planet's largest and fastest-forming geological features. They are sites of significant geohazards including volcanic eruptions, earthquakes, landslides, and tsunamis. Seismic monitoring is therefore crucial for detecting magmatic movements and issuing pre-eruptive warnings, as well as for understanding the internal structure of islands, thereby aiding in hazard and risk mitigation.

Studying volcanic islands poses challenges due to the complex processes occurring at depth and the logistical constraints imposed by the islands' size, shape and/or location relative to other islands. To overcome this, there is a critical need to densify seismic networks with land-based and ocean-bottom seismometers to enhance geographical coverage. This will enable better imaging of the subsurface and detection and classification of seismic signals associated with volcanic and tectonic activity. Generating 3D models from the shallow crust to the deep mantle, combining multiple seismic and other geophysical techniques is essential for understanding the geodynamic processes driving magma ascent and volcanism.

Our Research Topic, "Challenges in seismology to our understanding of volcanic islands and their magmatic unrest" features four original research articles. These articles explore dynamic subsurface changes and fluid migration during eruptions, innovate volcano-monitoring methodologies, and examine the complex mantle structures beneath volcanic islands, enhancing our understanding of the processes occurring before and during eruptions, and geodynamic constraints.

Civiero et al. conducted a comprehensive review of studies focusing on the complex mantle structure and transition zone beneath the Macaronesian volcanic islands in the central-eastern Atlantic (comprising the Azores, Madeira, Canaries, and Cape Verde). Their analysis underscored regional models which illustrate low-velocity features in the asthenosphere and a notably thinned transition zone, suggesting that these characteristics are due to mantle plumes. Additionally, these tomographic models were found to be consistent with global mantle tomography models. The authors also explored alternative theories that attribute volcanism to mechanisms related to mantle upwellings and plate tectonics, offering a broader perspective on the underlying geodynamic processes.

Continuous monitoring of active volcanoes for early warning and eruption forecasting continues to pose significant challenges. Addressing this, Fenner et al. utilized the Adaptive-Window Volcanic Event Selection Analysis Module (AWESAM) on several island volcanoes, including Stromboli and Etna in Italy, Yasur in Vanuatu, and Whakaari in New Zealand. Their study aimed to detect characteristic patterns in the recurrence times and overall volcanic activity. The findings revealed that, despite geographical differences, similar traits were consistently observed across all studied volcanoes in terms of amplitude-frequency relations, inter-event time distributions, and amplitude distributions. This consistency underscores the effectiveness of AWESAM in providing reliable data for volcanic monitoring.

Significant changes in the structure of volcanoes, driven by magma movement, are crucial to the forecasting of future eruptions. Shear-Wave Splitting (SWS) is an effective technique for assessing crustal and mantle anisotropy. Schlaphorst et al. used crustal SWS in an attempt to detect changes in the anisotropy pattern linked to volcanic unrest. The authors document the temporal variations in seismic anisotropy before, during, and after the 2011-2012 eruption offshore El Hierro and the 2021 eruption in La Palma in the Canary Islands. The two years following the El Hierro eruption show clear evidence of intrusive events. Following a period of relative calm, an uptick in results from El Hierro since 2018 suggests renewed subsurface activity in deeper parts of the system, impacting overall seismicity rates but not vertical GPS measurements concurrently. In La Palma, subsurface dynamic changes were observed in the week leading up to the 2021 eruption.

Ambient seismic noise interferometry is a cost-effective and high-sensitivity tool to detect and analyze changes in velocity related to subsurface changes over time and space. In their study, Carvalho et al. applied auto- and cross-correlation functions of ambient seismic noise to assess temporal structural changes induced by magma movement in La Palma between 2020 and 2022. Their findings indicate a significant decorrelation prior to the eruption, which is primarily attributed to the ascent of hydrothermal fluids. A marked increase in decorrelation was also noted at the onset of the eruption. Post-eruption observations revealed that, while some deeper parts of the plumbing system remained pressurized by hydrothermal fluids, the shallow structures experienced minimal changes and quickly returned to the pre-eruptive state.

This Research Topic underscores the ongoing efforts and advances in understanding and monitoring volcanic islands, demonstrating the critical role of integrated seismological studies in managing volcanic hazards and associated risks, and improving forecasting capabilities.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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