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Editorial: Linking subaqueous, subglacial, and subaerial volcanism: how water influences eruption dynamics and creation of volcanic products

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Editorial on the Research Topic
Linking subaqueous, subglacial, and subaerial volcanism: how water influences eruption dynamics and creation of volcanic products

This Research Topic addresses the latest volcanological advances concerning magma-water interactions and their distinctive landforms and eruptive products wherever they occur, in the hydrosphere, cryosphere or atmosphere. The common thread of this article Research Topic, which contains nine contributions is the involvement and impact of magma interacting with water in all its forms, including snow and ice. It seeks to improve our understanding of the different ways in which water affects volcanism, including eruptions with only minor water input but which materially transforms the resulting eruptive processes in distinctive ways.

Water is ubiquitous on Earth and interaction with magma is common, however many processes involving magma-water interaction are only partially understood. Most of Earth's volcanism takes place in submarine settings, particularly at mid-oceanic ridges and oceanic arcs, but the vast majority of eruptions involving water, including those occurring under ice, are unobserved, thereby limiting our understanding of the eruptive processes and mechanisms involved. Being able to reliably detect new eruptive events that occur under the sea surface is an important step forward towards better understanding submarine eruptions. Using machine learning techniques, a novel analysis framework developed by Zheng et al., will help researchers to uncover new submarine eruptions by semi-automatically identifying active pumice rafts recorded in high-definition global satellite imagery. This technique is particularly relevant for eruptions occurring at remote seamounts that may not be detected by any other type of warning system. An example for how modern technological advancements enhance our capabilities to monitor eruptive processes in deep-sea settings with increasing detail is provided by Saurel et al. Their study describes how hydro-acoustic signals can be utilized to reconstruct the short-term spatial evolution of submarine lava flows and constrain the effusion rates.

Analysis of deposits from subaqueous eruptions is another crucial instrument to shed light on relevant eruptive processes. Using geochemical analysis of submarine samples, Tamura et al. not only confirmed that a shift from effusive to more explosive volcanism at Nishinoshima Volcano (Japan) was coincident with a change in magma composition, but used trace elements and isotopic analysis to fingerprint the source conditions of the magmas (see Figure 1).

The eruptive style is considerably influenced by external water, resulting in powerful explosions that fuel phreatomagmatic eruptions and generate fine ash that can be difficult to forecast and, at another extreme, may be implicated in devastating poorly understood violent-Strombolian events. Volcanologists distinguish between two thermohydraulic explosion mechanisms (Dürig et al., 2020a): molten fuel-coolant interaction (MFCI) and induced fuel coolant interaction (IFCI). In IFCI, water acts as a "thermohydraulic wedge," which boosts the efficiency of a primary magma fragmentation process. IFCI was identified as a key driver for an explosive phase that produced fine tephra during the 2012 eruption of Havre volcano (Dürig et al., 2020b), a submarine caldera which is situated in the Kermadec arc. MFCI, on the other hand, requires a pre-mixing phase, during which the magma is separated from the liquid phase of water by a thin vapor film (Büttner and Zimanowski, 1998). The experimental findings of Sonder and Moitra help us to better understand the complex physical mechanisms that sustain such a vapor film, and explain why the stability of the vapor film decreases under increasing ambient pressures, reducing the likelihood of MFCI to occur.

Finding out what controls the efficiency of MFCI explosions is also the research focus of the study by Schmith and Swanson, who combined field observations with granulometric and morphometric analysis of ash samples to examine how magma structure and magma-water mixing conditions controlled phreatomagmatic explosions at Kīlauea Volcano, Hawaii.

The dynamics of subglacial eruptions are fundamentally controlled by the presence (or absence) of water, be it in the form of snow, ice, or meltwater, whilst the resulting landforms can be different due particularly to the physical constraints of eruptions confined by ice. This is unusually well demonstrated by multiple monogenetic volcanic edifices that are part of the Mount Melbourne Volcanic Field in Antarctica, within the West Antarctic Rift System, described by Smellie et al. They erect a hierarchy of landforms that reflects the different eruptive conditions (water, ice) experienced by erupting magmas and which was used to define the varying environments that prevailed in the volcanic field over the last 4 million years. Exceptional sections exposed across a pillow-dominated volcanic ridge at Undirhlíðar, Iceland, also permitted Pollock et al. to demonstrate that alternating effusive and explosive eruptions were involved in its construction. The ridge was also fed incrementally in space and time by multiple magma batches from separate crustal magma bodies, thus shedding light on the unexpectedly varied physical and compositional processes involved in a seemingly simple pile of pillow lavas erupted in a glacial setting.

Understanding how glacial and deglacial effects influence eruption dynamics is also fundamental to better anticipating and thus mitigating

FIGURE 1
Scales of volcanism in marine environments modified from Tamura et al. **(A)** Slightly emergent edifice of Nishinoshima Volcano, Japan. The height of the central cone is ~250 m. **(B)** Sampling of Nishinoshima submarine tephra deposits by a remotely operated vehicle. **(C)** Scoria particles recovered from the tephras in **(B)**.

future hazards. Conway et al. review the time-volume-composition trends for 33 Pleistocene-Holocene volcanoes worldwide and examine the impact of changes in glaciation on erupted volumes and compositions of the edifice-forming products. Despite the apparent link between rapid deglaciation, release of crustal stress and enhanced eruption rates, the study showed that such a link is still difficult to demonstrate unambiguously due to ongoing limitations in the published datasets, particularly a lack of reliable chronologies.

Experiments with simple materials can often illustrate complex geological processes better than complicated scientific texts, and attract young budding scientists into scientific careers. Conway et al. present a series of innovative, fun and informative experiments using everyday kitchen materials to illustrate what happens when effusive eruptions occur on ice-clad volcanoes. They show how the presence or absence of ice affects the physical distribution of the lavas and thus influences the construction of volcanoes in many important ways.

The studies of this Research Topic highlight the continued value of multipronged research avenues including direct observations of eruptions, deposit characterizations, petrologic investigations and analogue experiments to better understand the physics, hazards, and records of magma water interactions around the globe. We cannot understand these complex systems without attacking them from all angles as demonstrated in this research volume.

Author contributions

TD: Conceptualization, Writing–original draft, Writing–review and editing. KF: Writing–review and editing. AG: Writing–review and editing. MJ: Writing–review and editing. JS: Writing–review and editing.

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.

Publisher's note

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