

PREFACE

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Special issue “magma migration and eruptions in a volcanic group: case studies for the 2017–2018 activity of the Kirishima Volcano Group and other global examples”

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Graphical Abstract



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Volcanic groups with multiple edifices located close to each other are relatively common around the world. Understanding the magma supply system beneath such volcanic groups and the relationships between eruptive activities across different edifices is a subject of great interest. Mt. Kirishima, consisting of more than twenty isolated eruption centers forming small edifices, serves as a notable example. Shinmoe-dake, one of its active cones, produced a magmatic eruption in 2011. A variety of instruments were deployed around Shinmoe-dake to provide multidisciplinary observations of its eruptive activity, many of which were also used during the 2018 eruptions. Eruptions in 2018 occurred at two edifices—Shinmoe-dake and Iwo (Io)-yama. At Shinmoe-dake, an effusive eruption occurred following the explosive eruption in 2011 and small explosive events in 2017, accompanied by subsidiary Vulcanian eruptions. Iwo-yama experienced phreatic explosions, the first such activity since 1768. The extensive observational data and in-depth analysis of the 2018 eruptions present a significant opportunity to enhance our understanding of the magmatic system within the volcanic group. This special issue presents the latest insights into magma systems beneath volcanic groups and the mechanisms of associated eruptions using data from geophysical, geological, and geochemical investigations. The following results are presented:

New results were presented from the analyses of geophysical observation data. Kurihara and Kato (2022) presented a comprehensive study of deep low-frequency (DLF) earthquakes related to the 2018 eruptions at the Kirishima volcano group. Although the total DLF earthquake activity associated with the 2018 eruptions was much weaker than that for the 2011 eruptions, the temporal evolution of DLF earthquake activity was consistent with surface volcanic unrest and shallow deformation, similar to the observations during the 2011 eruptions. They interpreted that a deep magma supply influenced both eruptions, but the magma pathways might have been different in 2018 from 2011. Yukutake et al. (2023) applied a machine-learning approach to reexamine volcanic earthquakes at the Kirishima volcano over the past 12 years. They identified approximately 6.2 times more earthquakes than a conventional seismic catalog and obtained a high-resolution hypocenter distribution. They found earthquake events temporally and spatially consistent with recent eruptions and associated magma supply pathways that other multiparametric observations suggested. Konstantinou et al. (2022) studied seismic noise signatures before and after the 2011, 2017, and 2018 eruptions at Shinmoe-dake volcano, using a complexity metric called permutation entropy (PE). They found that the PE values decreased before each eruption and

spiked just before the onset of all three eruptions. They inferred the PE variations indicated the interaction of the ascending magma with the aquifer or solidified magma plug at shallow depths. Yoshinaga et al. (2023) analyzed extensometer and tiltmeter data focusing on subsurface magma movement during the early stages of the 2018 Shinmoe-dake eruptions. They found that deep magmatic activity began at 14:00 on March 5, approximately 19 h earlier than previously thought. They discussed the magma ascent from ~11 km below sea level to the surface in the early and main phases of the 2018 eruptions. Kozono et al. (2023) investigated magma storage conditions before the 2011 and 2018 eruptions at Shinmoe-dake by analyzing the relationship between geodetic volume change and erupted magma volume. They concluded under the assumption of a spherical magma chamber that the chamber was filled with bubble-free magma, suggesting efficient gas segregation before the eruptions.

Studies on the erupted materials have also been reported. Maeno et al. (2023) studied the transition between explosive and effusive eruptions at Shinmoe-dake volcano in 2017 and 2018 by analyzing surface phenomena, whole-rock chemistry, and microtextural properties of erupted pumice, ballistics, and lava. Although samples of the ballistics or lava and pumice from Vulcanian explosions right after the lava emplacement were comparable with the Vulcanian ballistics and the subplinian pumice from the 2011 eruptions, respectively, pumice erupted during the hybrid activity with simultaneous small-scale explosions and lava dome formation, characteristic to the 2018 eruptions, exhibited textures that were not observed in 2011. They interpreted the results as showing that the transitions in the eruption styles were primarily controlled by the ascent rate of andesitic magma and the geological structure beneath the summit crater. Saito et al. (2023) studied magma ascent and degassing during the 2011 and 2017–2018 eruptions of Shinmoe-dake, analyzing the petrological characteristics and volatile content of the magmas. Their chemical analyses of the whole rock and crystals revealed that the 2018 magma was a remnant of the 2011 magma because both had similar compositions. They explained the effusive nature of the 2018 eruptions by the relatively low volatile content of the 2018 magma compared with the 2011 magma that led to subplinian eruptions.

Integrating the above findings reported in this special issue, information published elsewhere, and their own analyses of aerial photographs, satellite imagery, and seismo-acoustic data, Ichihara et al. (2023) provided a detailed sequence of events during the 2017–2018 eruptions at the Kirishima volcano group. They proposed that the eruptions of Shinmoe-dake in 2017 and 2018,

as well as the 2018 eruption of Iwo-yama, were sequential events linked by the degassing of magma beneath Shinmoe-dake.

The continued surface activity at Shinmoe-dake and Iwo-yama after the main eruptions in 2018 made the Kirishima Volcano Group a natural laboratory for volcanologists. Ishii et al. (2023) developed a method to predict ash concentrations in volcanic ash clouds using the Himawari-8 satellite and an atmospheric transport model and tested it with the April 4, 2018, Shinmoe-dake eruption. They introduced a wind shear index and optimized its parameter to estimate ash cloud thickness immediately after an eruption. The proposed method will provide helpful information to assess safe areas and routes for airline operations. Miyabuchi et al. (2023) investigated the dispersal and grain size characteristics of the May 14, 2018, Shinmoe-dake eruption deposits immediately after the eruption. They demonstrated that the spatial and grain-size distributions of the tephra fall deposits can generally be explained by the eruption style and vertical wind profile over the source volcano but put forward the need to solve the inverse problem to accurately reconstruct the vertical profile of the volcanic ash plume in the atmosphere. Tanabe et al. (2023) performed multiparametric observations at Iwo-Yama's West Crater and explored the cause of cyclic hydrothermal water discharge. They proposed that the inflow of cold groundwater into the geyser conduit controls the cyclicity of hydrothermal water discharge by inhibiting boiling and building up pressure until discharge occurs. Yamakawa et al. (2023) conducted an experiment at Iwo-Yama using a very-small-aperture infrasonic array and a near-vent single microphone. They successfully resolved the two fumarolic sources and demonstrated the utility of their microphones and methods for volcanic monitoring.

The Special Issue also includes studies on similar phenomena at other volcanoes. Massaro et al. (2022) reconstructed the evolution of discharge rates at the Santiaguito lava dome complex in Guatemala from 1922 to 2021, combining new satellite thermal data. They identified three key periodicities: (i) long-term cycles lasting approximately 10 years, (ii) intermediate-term cycles lasting around 3.5 years, and (iii) short-term cycles ranging from 1 year to 3 months. These periodicities were similar to those observed in other lava dome eruptions at calc-alkaline volcanoes. Shinmoe-dake exhibited more sporadic lava effusions, and each of the 2011 and 2018 effusion events lasted a few days. Petrelli et al. (2023) reviewed pre-eruptive dynamics and open-system behavior in the volcanic plumbing system beneath Campi Flegrei Caldera in Italy, focusing on magma ascent and mixing-to-eruption timescales. They suggested that explosive eruptions could occur

with minimal warning, as magma ascent could be fast and mixing timescales could be as short as minutes to hours. The recent studies included those in this special issue reported new observations indicating magma movement before the Shinmoe-dake eruptions (Ichihara et al. 2023; Konstantinou et al. 2022; Kurihara and Kato 2022; Yoshinaga et al. 2023; Yukutake et al. 2023), the magma mixing timescales at Shinmoe-dake have not been constrained, yet. The simultaneous activation of the DLF at tens of kilometers deep and the shallow and surface phenomena was one of the unique observations at the Kirishima Volcano Group (Kurihara and Kato 2022). Yukutake et al. (2022) reported a deep harmonic volcanic tremor event related to DLF earthquakes at Hakone volcano. They estimated the tremor source as deep as 40 km beneath the volcano, in the extension of the DLF earthquake hypocenters near the Moho discontinuity. The DLFs activated immediately before the tremor onset and continued for several months. Ozaki et al. (2023) updated a nonlinear flow-induced tremor model. Combining the model solution with the Green's function, they successfully reproduced the observed deep tremor waveforms at the Hakone volcano. Their results supported Yukutake et al. (2023) that the tremor signified the migration of magmatic fluid in the volcano's deep region.

As summarized above, this special issue compiles a diverse range of findings from the 2017–2018 activities of the Kirishima volcano group, as well as similar cases worldwide. A key takeaway from these studies is that the subsurface structure and magma plumbing system beneath a volcanic group with multiple edifices are highly complex, emphasizing the need for further research to deepen our understanding. Fortunately, the observation network at the Kirishima volcano group has been consistently maintained at a high level since the 2017–2018 eruption. In addition, several campaign observations, including electromagnetic surveys and high-density seismic array studies, have been conducted. It is expected that, by analyzing the data collected, we will gain a more accurate understanding of the magma systems beneath volcanic groups and the associated eruption mechanisms. The findings presented in this issue will serve as a solid foundation for future research in this field.

Author contributions

All authors of this article served as guest editors for this special issue. TK drafted the manuscript. All authors read and approved the final manuscript.

Availability of data

Not applicable.

Declarations

Competing interests

The authors declare that they have no competing interests.

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