Conduit flow dynamics during high-flux lava effusion events at Sakurajima volcano, Japan

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The ascent of multiphase magma in a volcanic conduit (a conduit flow) involves many complex processes such as vesiculation, gas escape, and crystallization, and it strongly controls eruption styles. By combining the modeling of conduit flow with some geological, petrological, and geophysical observations for eruptions, we can obtain detailed information on subsurface magma plumbing system. In this study, we investigated the conduit flow dynamics during lava effusion events in the historical eruptions of Sakurajima volcano, Japan by combining a 1-dimensional conduit flow model with the observed features of the lava effusion processes.

Lava effusion events during the four historical eruptions at Sakurajima volcano (1471-1476, 1779-1781, 1914, and 1946) are commonly characterized by effusions of andesitic magma from newly opened fissure vents radiating from the main summit, and the vents of the first three eruptions are symmetrically distributed with respect to the summit. Because these observations imply dike-like magma plumbing system during the lava effusion events, we added the effects of dike-like conduit geometry with an ellipsoidal cross-section to the previous conduit flow model by Kozono and Koyaguchi (2012). In the 1914 eruption, the lava effusion from the western flank showed an exponential decrease in the magma discharge rate. In the analyses of the conduit flow model, we obtain the relationship between chamber pressure (P) and magma flow rate (Q) in the steady conduit flow. When this relationship has a positive correlation, the conduit flow system becomes stable, leading to an exponential change in the magma flow rate. Therefore, we can identify magmatic and geological conditions for the exponential decrease in the magma flow rate to occur during the Sakurajima lava effusion event using the conduit flow model.

In the P-Q relationship, there are regions of positive correlation in the low-Q and high-Q ranges, whereas the negative correlation region is generated in the intermediate range by the effects of magma viscosity change due to crystallization and magma density change due to gas escape. When we define the maximum flow rate of the positive correlation region in the low-Q range (referred to as "Q_{cr}"), the region of $Q < Q_{cr}$ corresponds to the Taisho lava effusion phase. The results show that Q_{cr} strongly depends on the parameters related to the conduit geometry such as conduit radius and the ratio of the major to minor axes of the ellipsoidal cross-section. There are two competing effects of the change in the conduit radius on Q_{cr}. First, as the conduit radius decreases, vertical gas escape is promoted because of the suppression of the ascent of the liquid due to the increase in wall friction force, and lateral gas escape is also promoted because of the increase in the ratio of the perimeter to the area of the conduit cross-section. These promotions of gas escapes lead to more stable effusive eruptions, which corresponds to the increase in Q_{cr}. Second, as the conduit radius decreases, the area of the conduit cross-section decreases, leading to the decrease in Q_{cr}. When the ratio of the major to minor axes changes for a given minor axis, the second effect becomes predominant. We found that a drastic increase in Q_{cr} with increasing the ratio of the major to minor axes is necessary for satisfying the condition that Q_{cr} becomes greater than the observed maximum flow rate during the Taisho lava eruption (about 2400 m^3/s). This suggests that a dike-like conduit geometry played a key role on the high-flux lava effusion processes in the Sakurajima eruptions.

Keywords: Conduit flow, Sakurajima, Lava effusion

