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Effects of lateral gas escape on transitions from lava dome eruptions to explosive eruptions

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During lava dome eruptions, gas phase can escape from magma in two different ways: lateral gas escape through the conduit wall and vertical gas escape through the magma to the vent. The competition between these gas escapes and vesiculation of magma leads to complex features of conduit flow such as a transition to explosive eruptions. In this study we investigated how the gas escapes control the dynamics of lava dome eruptions on the basis of a steady or time-dependent 1-dimensional conduit flow model in which both the lateral and vertical gas escapes are taken into account.

Transitions from lava dome eruptions to explosive eruptions can be predicted by the relationship between pressure at magma chamber (p) and magma flow rate (q) at steady state (referred to as the p-q curve). The conduit system is stable when the slope of the p-q curve (dp/dq) is positive, whereas it is unstable when dp/dq is negative. We systematically investigated the features of the p-q curve on the basis of the steady conduit flow model. Results show that the p-q curve is sigmoidal under some realistic conditions: dp/dq is positive in the low-q and high-q regimes, and it is negative in the intermediate regime. In the low-q regime, the magma porosity inside the conduit is extremely low because of effective lateral and vertical gas escapes. This regime corresponds to the conduit flow of stable lava dome eruptions. The conduit flow in the high-q regime, on the other hand, is characterized by a high porosity. In this case the effect of lateral gas escape is negligibly small compared with that of vertical gas escape.

We investigated the time evolution in the features of the conduit flow in the case that the p-q curve is sigmoidal on the basis of the time-dependent conduit flow model. This model assumes that the change in the pressure at the magma chamber is controlled by the balance between magma supply from depth to the magma chamber and magma effusion from the chamber to the conduit. Our results show that, because of the sigmoidal shape of the p-q curve, magma discharge rate abruptly increases from the low-q to high-q regimes as magma supply gradually increases at depth; this jump corresponds to a transition from lava dome eruptions to explosive eruptions. This implies that the transition of eruption styles is associated with the change from lateral gas escape to vertical gas escape.

Keywords: lava dome eruptions, gas escape, transition of eruption styles, magma ascet, conduit flow, numerical model