Effects of gas escape and crystallization on the complexity of conduit flow dynamics during lava dome eruptions

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Muon radiography is a promising method to estimate porosity distributions of magma in volcanic conduits. Because the degree of gas-escape from magma, and hence, the porosity distributions in conduits strongly control the dynamics of conduit flow, this method is expected to provide important information about the dynamics of volcanic eruptions such as transition from a lava dome eruption to an explosive eruption.

We developed a 1-dimensional conduit flow model in order to investigate how gas escape from magma and crystallization control the dynamics of conduit flow during lava dome eruptions. Generally, the dynamics of viscous pipe flow is determined by the relationship between source pressure and mass flow rate ("the p-q relationship"). When the slope of the p-q relationship (dp/dq) has a positive value at a steady flow, the steady flow is stable. When dp/dq has a negative value, on the other hand, complex dynamics such as abrupt change and/or cyclic change of magma discharge rate can result. Our results show that the p-q relationship is sigmoidal under some realistic conditions for conduit flow involving gas escape and crystallization: dp/dq is positive in the low-q and high-q regimes, and it is negative in the intermediate regime. The low-q regime is characterized by extremely low magma porosities in the conduit; it corresponds to a stable lava dome eruption. The conduit flow in the high-q regime is characterized by high porosities. In the intermediate regime, average porosity in the conduit increases with increasing mass flow rate. The reduction of gravitational load with the increasing mass flow rate causes the negative dp/dq in this regime. The analyses of time-dependent conduit flows indicate that, because of the sigmoidal p-q relationship, magma discharge rate abruptly increases from the low-q to high-q regimes as magma supply gradually increases at depth. It is suggested that transition from a lava dome eruption to an explosive eruption is accompanied with a drastic increase in porosity inside the conduit.