An analytical study for 1-dimensional steady flow in volcanic conduit

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The effects of magma properties (viscosity and volatile content) and geological conditions (radius and length of conduit) on the dynamics of explosive eruptions are analytically investigated on the basis of a simplified model for 1-dimensional steady flow in a volcanic conduit. In the simplified model, it is assumed that the pressure and velocity of gas and liquid phases are identical, and that magma fragmentation occurs when gas volume fraction reaches a critical value.

The conduit flow is characterized by bubbly flow before magma fragmentation and by gas-pyroclast flow after magma fragmentation. The features of the flow are largely determined by the balance of viscous effects of the bubbly flow and expansion of the gas-pyroclast flow under a given boundary condition. Those effects are described by two non-dimensional numbers, A and B. The parameter A represents the ratio of effects of wall friction and gravity in the bubbly flow; the length of the bubbly flow region decreases as A increases. The parameter B represents the ratio of pressures at the vent and at fragmentation level; the length of the gas-pyroclast flow region decreases as B increases. Three regimes of conduit flow are defined according to B/A. When B/A is smaller than a certain value determined by initial volatile content and length of conduit, the conduit flow is composed mainly of the gas-pyroclast flow region (Regime 1). On the other hand, when B/A is greater than 10, the conduit flow is composed mainly of the bubbly flow region (Regime 3). Regime 2 is the intermediate regime between Regimes 1 and 3. The flow variables such as level of fragmentation and magma discharge rate are sensitive to magma properties and geological conditions in Regime 2. On the basis of this analytical approach, a method to estimate eruption rate and depth of fragmentation surface without computer is proposed.