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# Numerical simulation of magma ascent process in an open conduit based on a one-dimensional conduit flow model

# Ryohei Kawaguchi[1]; Takeshi Nishimura[1]; Haruo Sato[1]

[1] Geophysics, Science, Tohoku University

Volatile behavior in magma is a key to understand the dynamics of volcanic eruption. Recent geodetic observations at active volcanoes showing Vulcanian or Strombolian type eruptions show volcano inflations prior to each eruption. Theoretical considerations on the magma ascent in the conduit based on a basic process of magma flow or gas bubble growth indicate that magma ascent rate or volcano deformation are related to the existence of gas bubble growth in magma. In this study, we simulate the magma flow in the conduit before eruption by using 1-D conduit flow model in which gas bubble growth process is taken into account.

When volcanoes repeatedly erupt with a short time interval, the volcanic conduit is considered not to close after each eruption. Here, we can apply a 1-D conduit flow model for the magma ascent, neglecting the effects of the opening and closing the conduit. A short duration eruption can decompress the magma in the conduit in a short time. So, the melt solubility decreases and volatile supersaturates in the melt. On the other hand, gas bubbles in magma can not expand sufficiently because of viscous resistance from the melt. However, as the time proceeds, the gas bubbles slowly grow due to pressure difference built up between the gas bubbles and melt and due to mass flux of volatiles from supersaturated melt. Volume expansion caused by the gas bubble growth as well as pressure gradient generated in the conduit lift magma up in the conduit. We consider the magma flow in the conduit having a constant diameter. The magma contains tiny gas bubbles in melt. We assume that relative velocity between gas bubbles and melt is zero. We express the magma flow using the equation of mass conservation, the equation of momentum conservation, and the equation of state of gas phase and liquid phase. The gas bubble growth processes is formulated by the equation of motion for the gas bubble and melt interface and the diffusion equation of volatiles in melt. These equations are characterized by the Poiseuille flow time scale that is determined from the shape of the conduit and density and viscosity of the melt, the viscosity deformation time scale that is determined from the initial pressure difference between bubble and melt, the diffusion time scale that is determined from the bubble number density and diffusion coefficient of volatile. The pressure at the top of the magma in the conduit is set to be equal to the atmospheric pressure and the pressure at the bottom of conduit is fixed at the reservoir pressure. We calculate magma flow in the conduit by applying a finite difference method.

We examine one case of the magma flow in the conduit by setting a possible melt and gas pressure distributions in the conduit that linearly increase with depth as an initial condition. The simulation shows the following results. When magma does not contain gas bubbles, the rate of magma ascent in the conduit decreases with time because the driving force of magma is only the pressure gradient between the top of magma and the reservoir, which decreases as the magma ascends. While, when magma contains gas bubbles, the magma ascent rate change with the ratio of viscous deformation time scale to Poiseuille flow time scale R. For the magma with R of about 1, the magma ascent rate is almost constant and is proportional to time. This is because gas bubbles growth act as a driving force during the magma ascent. On the other hand, when R is a small enough, gas bubbles can grow faster and reach the equivalent before the magma reaches the surface. So, the magma ascent rate gradually decreases as the case of magma without gas bubbles.

Our simulation indicates that the magma ascent process in conduit is affected by gas bubble growth in magma. Observation of the time variation of pressure source in the conduit, which may be represented as ground deformation data, may enable us to evaluate the physical properties of magma and conduit shape.