Effects of magma flux and viscosity on porosity change of an ascending magma in volcanic conduits during dome-forming eruptions

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In dome-forming eruptions, the increase in magma porosity due to vesiculation during magma ascent is suppressed by efficient escape of gas from magma, leading to complex porosity change of magma in volcanic conduits. Previous numerical studies of conduit flow model have shown various porosity profiles in conduits (e.g., Melnik and Sparks, 1999; Diller et al., 2006). Recent cosmic-ray muon radiography imaging of volcanoes also shows heterogeneous distribution of magma density (i.e., porosity) in conduits (e.g., Tanaka et al., 2009). In order to systematically understand the porosity change during magma ascent in dome-forming eruptions, we analytically investigated essential factors controlling the porosity change on the basis of a 1-D steady conduit flow model that considers vertical escape of gas from magma.

We obtained an analytical expression describing how the porosity depends on magmatic and geological parameters in conduits. The analytical expression shows that the porosity decreases with increasing (magma viscosity)/(conduit radius)^2. In addition, when (magma viscosity)/(conduit radius)^2 is smaller than about 10^8 Pa s m^{-2}, the porosity sensitively depends on magma flux; it increases with increasing the magma flux. On the other hand, when (magma viscosity)/(conduit radius)^2 is larger than about 10^8 Pa s m^{-2}, the porosity is independent of the magma flux.

The above results indicate that the porosity profile in the conduit is largely affected by the magma viscosity in the conduit. The viscosity increases drastically from about 10^6 to 10^{14} Pa s during magma ascent by the effects of volatile exsolution and crystallization. Since the viscosity near the surface is sufficiently high because of efficient volatile exsolution and crystallization, the porosity near the surface is small, and in addition, it is independent of the magma flux. On the other hand, in the region from magma chamber to beneath the vent, the viscosity is not so high because of low crystallinity. In this region, the porosity profile largely changes depending on the magma flux. Our results give constraints on conduit system by comparing with the density (i.e., porosity) distribution in a conduit estimated by field observations such as muon radiography.