Density distribution of magma in the conduit of Mt. Iwodake, Satsuma-Iwojima volcano:2. Conduit Magma Convection Model

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The Muon radiography conducted at Mt. Iwodake, Satsuma-Iwojima volcano revealed a low density region just beneath the summit crater of Mt. Iwodake, and the low density region is interpreted as vesiculated magma in a conduit. This is the first direct evidence of the conduit magma convection, whose top is located shallow depth beneath the summit crater. We will introduce the conduit magma convection model inferred for the Satsuma-Iwojima volcano and discuss the implication of the density structure obtained by the muon radiography and the newly obtained constraints to the conduit magma convection model.

Emission of the large amount of high-temperature volcanic gases, with SO2 flux of 1000t/d, continued for more than hundreds of years at Satsuma-Iwojima. The continuous volcanic gas emission requires that the gases are supplied from a deep magma chamber to the surface by the conduit magma convection. The conduit magma convection model recently becomes to be accepted as a reasonable model for basaltic volcanoes, but is not yet well tested for dacitic to rhyolitic volcano, such as Satsuma-Iwojima volcano. Several studies, such as observation of the high-temperature fumarolic gases, volatile contents in melt inclusion etc (e.g., Saito et al., 2001), suggested the shallow magma degassing. However, it is not evident that the magma is actively degassing at near-surface beneath the summit crater, where magmatic eruption did not occur more than several hundreds of years, and the conduit magma convection model is required to be proved by more direct evidence.

The muon radiography at Mt. Iwodake revealed that the low density region of 0.5 g/cm3 with a diameter of 160m locates beneath the summit crater down to the depth of 280m (Tanaka et al., This Meeting). Since the averaged density of the volcanic edifice is 2.0g/cm3, the low density region corresponds to the porosity of 75%. Such highly porous materials are not stable underground, in particular under the extremely severe condition at the Iwodake summit which is highly altered by the acid and high-temperature volcanic gases. Therefore the low density region most likely corresponds to a highly vesiculated magma with porosity up to 80%.

Magma density decreases with decreasing pressure because of exsolution of volatiles and expansion of the exsolved gases. But highly porous magma tends to have a large gas permeability, which causes outgassing from the magma resulting in density increase, implying that the highly vesiculated magma is not stable. In order to maintain the low density region by the vesiculated magma, the vesiculated magma needs to be continuously supplied to replace the degassed magma. Therefore, the low density region at upper part of the volcanic conduit is considered as the direct evidence of the conduit magma convection reaching to the near surface.

The large viscosity of rhyolitic magma requires a large volcanic conduit for the conduit magma convection. Based on a simple fluid-dynamic model, Kazahaya et al. (2002) estimated that the conduit diameter needs to be larger than 100 m for the magma convection to cause the observed flux of volcanic gases. The 160 m diameter of the low density region agrees well with this estimate. The low density region is significant at near-surface, but becomes unclear at depth deeper than 280 m from the crater bottom. This density increase with depth might be caused by the changes of the distribution of low-density ascending magma and high-density descending magma with decrease of the diameter of the magma ascent flow at depth deeper than 280m. The density structure revealed by the muon radiography provides not only the evidence of the conduit magma convection but also the constraints to the size, shape and flow pattern of the magma convection.