The 1991-1995 dome forming eruption of Unzen volcano: effect of magma pocket on the magma mixing process

Eiichi Sato[1]

[1] Earth and Planet. Sci., Graduate School of Sci. and Tech., Kobe Univ.

http://www2.kobe-u.ac.jp/~032d839n/eiichi.html

Dacite of the Unzen 1991-1995 eruption shows that magma mixing between high-Temperature and low-Temperature magmas occurred, although the dacite is similar in SiO_2 content (SiO_2 = 64.5-66 wt.%) during the eruption (Nakada and Motomura, 1999). In previous studies on the magma mixing of Unzen 1991-1995 eruption, estimations of end-member magmas (e.g., temperature, chemical compositions and water contents) have mainly been investigated. Physical mechanism of magma mixing, however, has not been documented. In the Unzen volcano, geophysical studies showed that magma uprose from the magma chamber located at a depth of 15 km (Umakoshi et al., 2001) and passed through the three magma pockets (A: 0.6 km, B: 4 km, C: 7 km in depth, Hendrast et al., 1997). In this study, we present the physical mechanism of magma mixing, using results of an analogue experiment (Sato and Sato, 2007), which was carried out to examine an effect of a magma pocket on the magma mixing process. In the analogue experiment, Sato and Sato (2007) showed condition of mixing of two liquids of different densities and viscosities, using a dimensionless parameter I ($I = vU/(g(d_2\text{-}d_1)R^2)$, Koyaguchi and Blake, 1989). Where v is viscosity of the viscous liquid, U is velocity, g is acceleration due to gravity, d_2-d_1 is density difference between the two liquids, and R is radius of pipe. When I is less than 0.1, the two liquids showed gravitational instability in a pocket illustrating mingling of the two liquids, whereas the two liquids kept annular flow without mingling when I is more than 0.1.

In the Unzen 1991-1995 eruption, initial dome growth occurred at 300000 m^3/day, corresponding to 3.5 m^3/s. If we assume initial conduit diameter of 10-30 m, average uprise velocity is calculated to be 0.0049-0.044 m/s, and travel time of magma from the magma chamber (15 km in depth) to surface is 5.3 to 47.2 days. Time scale of magma mixing of the Unzen volcano using diffusion profiles of titanomagnetite indicated evidence of short time interval between mixing and extrusion (ca a few days to months, Nakamura, 1995). Thus, mixing of magmas may have occurred in the conduit. We estimated densities and viscosities of end-member magmas based on chemical compositions of the end-member magmas (Holtz et al., 2005), and Reynolds number in the conduit is calculated to be 0.0001 to 0.01. This value does not satisfy the condition of magma mixing in the conduit (Re is more than 3, Blake and Campbell, 1986). If we assume that the diameters of magma pocket B and C are 100 m, parameter I are 0.003 to 0.03 and 0.0007-0.007, respectively. These values are good agreement with the mixing condition in the magma pocket (I is less than 0.1). Thus, presence of the magma pockets promoted gravitational instability of magmas, and may be an important factor of magma mixing in the Unzen 1991-1995 eruption.