Quantitative understanding of heat and mass transport in a cooling magma chamber beneath Rishiri Volcano

Takeshi Kuritani[1]; Tetsuya Yokoyama[2]; Eizo Nakamura[3]

[1] Tohoku Univ.; [2] ISEI, Okayama Univ; [3] ISEI(Misasa), Okayama Univ.

In a cooling magma chamber, various kinds of instability occur as a consequence of heat transfer, and magmatic differentiation proceeds through combinations of some dynamic processes, such as thermal convection in the molten portion of the magma body (the main magma), compositional convection involving the mushy boundary layer, and gravitational settling of crystals in the main magma. In this study, rates of mass and heat transport in a magma chamber beneath Rishiri Volcano are estimated using information obtained from basaltic and andesitic lavas (Kutsugata and Tanetomi lavas, respectively).

The Kutsugata and Tanetomi lavas have been the subject of detailed petrologic and geochemical studies, and it is suggested that these lavas represent a series of magmas evolved by boundary layer fractionation due to compositional convection in the magma reservoir (Kuritani et al., 2005). The eruption age of the Kutsugata and Tanetomi lavas were estimated to be 40-50 ka and 20 ka, respectively (Kuritani et al., 2006a), by using U-Th disequilibrium. The thermal and chemical evolution of the magmas has already been modeled using constraints of mass and energy balance (Kuritani et al., 2006b). Unfortunately, however, the estimated age of the Kutsugata lava was a model age (assuming geochemical homogeneity of the source mantle, for example) and it is not so reliable. In this study, the eruption age of the lava is newly estimated by 14C dating of charcoals. In addition, we evaluate heat transport by compositional convection, to understand the mechanism of the cooling of the magma chamber.

Charcoals for the radiocarbon age dating were collected from a sand layer just underlying the Kutsugata lava. The result of the 14C dating shows that they formed at 29330 +/- 600 yBP (2sd). The age obtained in this study is significantly younger than 37320 yBP obtained for similar charcoals by Miura & Takaoka (1993). Unfortunately, we could not find a plausible reason for this discrepancy. However, Ishizuka (1999) determined ages of Middle-stage lavas, before the activity of the Kutsugata lava, to be 42 +/- 13 ka. And significant time interval is considered to have been present between the activities of Middle stage and the Kutsugata lava, because Middle-stage lavas are fairly eroded, in contrast to the Kutsugata lava which basically preserves original lava morphology. This observation infers that younger eruption age of the Kutsugata lava (i.e. longer time interval between the two activities) is more preferable, and we believe that the eruption age of ~29 ka is more plausible.

The melt transported from the mush zone by compositional convection can cool the main magma, if thermal equilibrium is not attained during the transport in the mush zone, and vice versa. The degree of thermal equilibrium during the melt transport in the mush zone is evaluated. It is assumed that, in compositional convection, the interstitial melt was transported with laminar flow to the main magma through stable vertical circular pipes. By utilizing the estimated physical parameters for the melt, it is suggested that the melt would have been thermally equilibrated with the surroundings during the transport by less than ~0.6 m. Therefore, it is expected that compositional convection could not have effectively cooled the main magma, and the cooling of the main magma is considered to have been caused principally by thermal convection in the Rishiri magma chamber.

From the results obtained above, we can estimate the rates of mass and heat transport in the Rishiri magma chamber using the model of Kuritani et al. (2006b). For example, the model calculations show that the volume flux of compositional convection and the convective heat flux decreased exponentially with time, from 0.3-10 to ~0.05 m/year and from 2 to 0.3 W/m^2, respectively, as the magma evolved from basaltic to andesitic compositions.