Plagioclase and biotite in holocrystalline composite dike record pre-solidification chemical diffusion in melt

*Ayu Yamazaki[1], Tetsuo Kawakami[1], Fumiko Higashino[2]

1. Department of Geology and Mineralogy, Graduate school of Science, Kyoto University , 2. Faculty of Science, Okayama University of Science

Magma mixing plays important roles in forming magmas of various compositions as well as in triggering volcanic eruptions (Perugini & Poli, 2012). Magmatic enclave (ME) originally crystallized from a part of discrete magma which intruded into a host magma with a different composition (Perugini & Poli, 2012). Since they crystallized before mixing completely, ME/host boundary can retain information about the magma mixing. For example, compositional profiles with a distance from ME/host boundary in volcanic glasses are reported (e.g. Perugini et al., 2003; Schreiber et al., 1999). Such profiles are determined in μm to mm scale and enable us to estimate timescales of chemical diffusion in some cases (e.g. Petrelli et al., 2006). On the other hand, compositional gradients across the ME/host boundary in plutonic rocks are usually determined by bulk-rock analyses, resulting in relatively rough (cm to dm) scales (e.g. Zhu et al., 2018; Wiebe, 1973; Eberz & Nicholls, 1990).

Yamazaki et al. (2019) investigated a holocrystalline composite dike (Ryoke belt, Japan) focusing on the systematic chemical change of minerals at ME/host boundary. In this composite dike, felsic host has simple mineral assemblage (Plagioclase (Pl) + Quartz (Qtz) + Biotite (Bt) ±rare garnet (Grt)). The Pl shows compositional zoning with core (An35-60), mantle (An25-35) and rim (An35-45) within a single grain. In addition, mm-scale compositional profiles are observed as changes of mineral compositions in a felsic host with distance from the ME/host boundary. With distance from the boundary, concentrations of MgO in Bt and CaO in Pl-rim are well fitted (R^2>0.80) by the solution of diffusion equation and their diffusion distances are the same order of magnitude. Therefore, these profiles are considered to have resulted from chemical diffusion in melt during magma mixing. The timescale of the diffusion is estimated to be less than 10^4 years. However, the geological meaning of this timescale has not been understood. In this study, the chemical profiles recorded in Bt enclosed in Pl are newly determined and its significance is discussed.

In the felsic host, some of the coarse-grained Pl include Bt in the mantle, and such Bt (simply referred to as "inclusion-Bt" below) shows compositional variation with distance from the ME/host boundary. The profile that MgO in inclusion-Bt showed was fitted by the solution of diffusion equation (Crank, 1956) and gave a good fitting result (R^2>0.70). The CaO content of Pl-mantle in the felsic host also shows a diffusion profile well fitted by the solution of diffusion equation (R^2~0.80). These diffusion distances are in the same order of magnitude. This observation suggests that the chemical diffusion in melt formed these profiles, because diffusion coefficients of Ca and Mg are almost same in melts (Mungall et al., 1999), while Fe-Mg interdiffusion in Bt is much faster than NaSi-CaAl interdiffusion in Pl (Liu & Yund, 1992; Usuki, 2002).

The diffusion distance of MgO in matrix-Bt is similar to that of the inclusion-Bt. Similarly, the diffusion distance that the profile of CaO in Pl-rim showed and that the Pl-mantle showed were the same. Assuming that the formation of the above diffusion profiles had started on the intrusion of ME into the felsic host and continued until the complete crystallization of the felsic host, the diffusion distance recorded by inclusion-Bt and matrix-Bt should be different; the former should be shorter than the latter. However, our observation showed that they are the same. This suggests that the formation of the diffusion profiles in the melt almost stopped soon after the crystallization of Pl-mantle.

Keywords: magma mixing, chemical diffusion, magmatic enclave