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Experimental simulation of mixing processes of crystal-rich and -free magmas

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Volcanic and plutonic rocks often show textural and petrological evidence on mixing of magmas with different chemical composition and temperature. Several experimental studies have been performed to reproduce textures found in natural rocks and to reveal the mechanism of magma mixing (e.g., Kouchi and Sunagawa, 1982; De Campos et al., 2008, 2011; Laumonier et al., 2014). Important processes that control magma mixing are crystallization and melting of crystals in magmas because they strongly change magma viscosity (Laumonier et al., 2014). For example, when magmas with different temperature contact and mix, crystallization and melting of crystals which are induced by thermal interaction are expected to occur in a hotter magma and in a colder magma, respectively. In addition, the crystallization in a hotter magma is enhanced by shear flow (e.g., Vona and Romano, 2013).

In this study, we experimentally simulated mixing processes of crystal-rich and -free magmas by using an image furnace. In experiments, crystal-rich rock samples with ~5 mm in an outer diameter (trachyandesite lava from Rishiri volcano and dacite lava from Unzen volcano) were contacted with a crystal-free glass, and then the samples were heated and twisted in the furnace. We used a glass sample synthesized from alkaline rock (trachyandesite lava) because it has relatively low viscosity even at 1 bar under dry conditions. The mixing experiments in the furnace were performed at a temperature of ca. 1100 ℃ (hot spot) under a shear rate of 4.2×10^{-2} s^{-1}. The samples were twisted for 6, 30, and 60 minutes. Because the glass sample synthesized at a temperature of 1400 ℃ is an undercooled melt at experimental temperature (1100 ℃), the crystallization of the melt is expected to occur, and this simulates cooling and crystallization of a hotter magma during magma mixing. After experiments, quenched run products were observed using optical and scanning electron microscopes.

In mixing experiments of the trachyandesite rock and the glass sample, the melting of crystals in crystal-rich magma was observed, while plagioclase crystallizes in crystal-free melt at the boundary of crystal-rich and -free magmas. The mingling between crystal-rich and -free magmas started to be found after 30 min. The mingling seems to enhance the crystallization in crystal-free magma. In a run product of a 60 min experiment, the part of originally crystal-free magma was highly crystallized. The experimental results indicate that the mingling between crystal-rich and -free magmas starts when melt fraction in the crystal-rich magma is high enough to cause the mingling, and it enhances the crystallization of originally crystal-poor magma, which results in rapid increase of magma viscosity. In contrast, the mingling was found only at a 60 min experiment for mixing experiments of the dacite rock and the glass sample. This difference between trachyandesite and dacite rocks may indicate that the onset of the mingling is controlled by the combination of crystal content in crystal-rich magma and the viscosity ratio of melt phases. Our experiments imply that the coupled effect of crystallinity change and mingling controls the mixing of magmas with originally different crystallinity, that is, different chemical composition and temperature.

Keywords: Magma mixing, Magma mingling, Shear flow, Crystallization, Viscosity