Forming process of the composite pyroxene crystals in ejecta of the Shinmoedake 2011 eruption

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The Shinmoedake 2011 eruption was characterized by a significant change in eruption style from sub-Plinian eruptions to lava effusion in the summit crater, and subsequent Vulcanian eruptions (Miyabuchi et al., 2013). Suzuki et al. (2013) reported that magma mixing occurred in two stages before the eruption, and that the timescale between the mixing of stage-1 and eruption was over 350 hours and that between the mixing of stage-2 and eruption was 0.7–15.2 hours. Moreover, they explained that magma mixing occurred between silicic andesite magma and basaltic andesite magma and then mobile mixed magma erupted with a part of silicic andesite magma.

Mujin et al. (2017) reported the minute crystals of pyroxene (~1 μm) in the product of the eruption with hexagonal crystal habit and an orthopyroxene (Opx) composition layer on the center of the crystal, of which both sides were augite (Aug). They explained that these composite pyroxene crystals reflected magma ascent process. However, the forming process of them has not been revealed fully yet.

The purpose of this study is to research the features of this composite pyroxenes (the size of several μm–tens μm) with similar features reported by Mujin et al. (2017) and to presume the forming process and the situation.

The samples were the pumice of sub-Plinian eruption and the pumice, fragments of volcanic blocks ~30 cm in diameter, and dense juvenile fragment of Vulcanian eruptions of the Shinmoedake 2011 eruption. To compare the different volcanos, the pumice of Plinian eruption of Sakurajima volcano was used in addition. These five samples were observed with scanning electron microscope (JSM-7001F, JEOL) and analyzed by energy dispersive X-ray spectrometry (X-Max^N 150mm^2, Oxford Instruments) to measure elemental composition. One composite pyroxene crystal in the dense juvenile fragment was analyzed by electron backscatter diffraction pattern (HKL CHANNEL5, Oxford Instruments) to reveal the crystal orientation.

The composite pyroxene crystals with Opx composition layers in the center were included in all the samples. Opx composition layers were 500 nm–several μm in width and spread on the center of the crystals parallel to (100). These composite pyroxene crystals had Al-zoning structures in the core. The composition of the rim of pyroxene phenocrysts (>100 μm) were different from the core which was massive and homogeneous. The composition of the composite pyroxene crystals were similar to the rim of pyroxene phenocrysts, and did not differ significantly among the samples. Furthermore, a composite pyroxene crystal (~40 μm) whose line profile of Opx composition layer along core to rim showed several peaks in Mg/(Mg+Fe) and Al concentration was observed.

From the above, the composite pyroxene crystals are thought to have been formed not only when the magma ascended in the conduit but also when magma mixing occurred in the magma chamber. Moreover, focused on the structure, Opx composition layers of the composite pyroxene crystals are too thick to be exsolved during the magma process proposed by Suzuki et al. (2013). In addition, the crystal whose Opx composition layer projected solely was observed. Therefore the composite pyroxene crystals are thought to be formed by the process that Aug nucleate heterogeneously on the (100) surfaces of the Opx composition particles. The result of this study suggests that the composite pyroxene crystals reflect the process of magma mixing in the magma chamber.