

Mineralogical characterization of groundmass nanolites in the Shinmoedake 2011 eruption products

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The groundmass nanolites are submicron scale minerals having a steeper slope of CSD (crystal size distribution) than microlites, originally described for a rhyolitic dome lava (Ben Lomond rhyolite lava dome; Sharp et al., 1996). The nanolites in explosive eruption products were first reported by Mujin and Nakamura (2014) for the pumices and dense juvenile fragments of the Shinmoedake (Kirishima Volcano) eruption in 2011. They found that the mineral assemblage of the nanolites recorded eruption style transition from sub-Plinian pumice, via Vulcanian pumice to lava cap as follows: pyroxene (pyx), pyx + plagioclase (pl), and pyx + pl + Fe-Ti oxides in a descending order of explosivity. In this study, we report their chemical compositions and crystal space groups.

The fine plagioclase microlites in the sub-Plinian pumices have clearly higher An contents (by ca. 5 mol%) than the similarly sized plagioclase (mostly nanolites) in the Vulcanian pumices and lithic fragments. This indicates that the pumices of Sub-Plinian eruption quenched before nanolite nucleation and growth of fine microlite ($<3 \mu\text{m}$ in width). The decrease in An content from the microlites to the nanolites may be explained by considering two factors: 1) crystallization differentiation of the melt, and 2) decompression and possibly cooling during crystallization.

The compositions of pyroxene nanolites and small microlites ($1 - 6 \mu\text{m}$ in width), on the other hand, do not show any systematic difference among the eruption styles, being consistent with the CSD results. They were within the metastable compositional range of pigeonite, sub-calcic augite and augite. In the electron diffraction pattern of TEM, we identified the pyroxenes and Fe-Ti oxide crystals as small of 20 and 10 nm in the dense juvenile fragments, respectively. In the HAADF-STEM images (Fig. 1), the pyroxene and Fe-Ti oxide crystals as small as 3 and 1 nm were discernable. Some Fe-Ti oxide crystals were formed on the pyroxene crystal surfaces, suggesting that some of the crystals nucleated heterogeneously. The crystal systems of pyroxene and Fe-Ti oxide nanolites were determined as $C2/c$ and $Fd\bar{3}m$, respectively. This is in contrast to the previously reported pyroxene nanolites in the lava dome sample (Sharp et al., 1996). They were composed of the mixture of orthopyroxene and clinopyroxene, and a complex micro-structure resulting from sub-solidus exsolution from pigeonite ($P2_1/c$) to augite ($C2/c$) and hypersthene. Sharp et al. (1996) interpreted this complexity of pyroxene phases resulted from moderate cooling rate within the obsidian layer. By contrast, we did not confirm the subsistent of the mixed pyroxenes in dense fragments of the Shinmoedake eruption products, because the scale of the observed pyroxene was 1 - 2 orders of magnitude smaller than that of Sharp et al. (1996). The appearance of a metastable phase of pyroxene nanolites and fine nanolites ($1 - 20 \text{ nm}$) in the dense fragments seems to be resulted from the nucleation and growth under large super cooling followed by rapid quenching. The large undercooling may have been produced though rapid magma ascent and succeeding dehydration and liquidus increase, in addition to the cooling and oxidation of the magma near the surface.

Keywords: Nanolite, undercooling, TEM, pyroxene, Fe-Tioxide, plagioclase

