

What can “nanolites” tell us about eruption styles?

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Crystallization of groundmass minerals record physicochemical conditions of magmatic processes upon eruption. Mujin and Nakamura (2014) reported that different assemblages of the nanolites in pyroclasts of the 2011 eruption of Shinmoedake, the Kirishima volcano, recorded the bifurcation conditions of the eruption styles. The pyroxene nanolite crystallized in both of the sub-Plinian products and the lava extrusion and Vulcanian products of the 2011 activity, whereas the plagioclase nanolite followed that of pyroxene only in the lava extrusion and Vulcanian products. They pointed out that the presence of plagioclase nanolites indicates the prolonged residence (or transit) time in the shallow conduit or crater (under large ΔT) at magmatic temperature prior to the lava extrusion and the Vulcanian explosions. The lack of plagioclase nanolite gives the upper limit of the duration in which the magma ascent through the shallow conduit in the sub-Plinian eruptions, whereas the appearance of plagioclase nanolite gives the lower limit of magma residence time for Vulcanian explosions.

Following their study, we report the presence of nanometer-scale crystals down to 1 nm in the pyroclasts from the Shinmoedake 2011 eruption and their mineralogical characteristics based on field emission-scanning electron microscopy and transmission electron microscopy.

The main finding regarding nanolite crystallization is a gap (hiatus) from ~ 100 to 30 nm in the size distribution of pyroxene in a dense juvenile fragment of a Vulcanian explosion. The finer-sized crystals of ~ 20 –30 nm were defined as “ultrananolites.” In the dense fragment sample, bright spots of ~ 1 –2 nm in diameter were recognized in high-angle annular dark-field scanning transmission electron microscopy images. These spots are presumed to be Fe–Ti oxide, although their mineral phase was not determined due to their small size. If so, the 1–2 nm crystals are ultrananolite with a ~ 9 nm gap from titanomagnetite nanolites. The pyroxene ultrananolite and Fe–Ti oxide nanolite and ultrananolite are assumed to have been formed by the additional increase in ΔT through cooling and oxidation, possibly by fragmentation followed by rewelding at the crater. Another important finding is that crystals smaller than a few tens of nanometers for pyroxene and a few hundred nanometers for plagioclase did not exist (or their number densities were too low for accurate determination). This indicates presence of practical minimum size of the crystals. These observations show that nucleation of the nanoscale crystals ceased, at least practically, in the late stage of groundmass crystallization owing to increased interfacial energy and decreased melt diffusivity in a dehydrated melt, whereas crystal growth was mostly continuous. The observation that pyroxene crystallization practically ceased before plagioclase nanolite appeared is consistent with the similarity in pyroxene characteristics such as the minimum crystal size of nanolite and the boundary size between microlite and nanolite between sub-Plinian and Vulcanian products, although plagioclase nanolites are found only in the Vulcanian products. The differences in the conditions between lava extrusions and Vulcanian explosions may be recorded in the later stage crystallization of plagioclase and Fe-Ti oxides.