Crystallization mechanism of groundmass nanolites inferred from the crystal size distribution of the Shinmoedake 2011 eruption

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Groundmass nanolites in pyroclastic rocks have a potential to indicate the physicochemical conditions of conduit magmas at transition points of eruption styles. Generally, the decompression and resulting degassing of ascending magmas produce the effective undercooling of hydrous melts, which drives crystallization of groundmass microlites (decompression-induced crystallization; e.g. Cashman and Blundy, 2000). Mujin and Nakamura (2014) reported presence of nanolites in the quenched products of the 2011 eruption of Shinmoedake, Kirishima volcanic group, Kyusyu Japan. They defined the nanolites of plagioclase and pyroxene in the dense juvenile fragments of the Vulcanian explosion on the basis of change of their crystal size distribution (CSD) slopes. They also found a gap in the CSD of Fe-Ti oxide and defined the finer nanometer-scale crystals as nanolite. In this study, we further define “ultrananolites” of pyroxenes and Fe-Ti oxide in the same sample as that investigated by Mujin and Nakamura (2014) based on a gap in CSD from the nanolites: between 300 and 30 nm for pyroxenes and between 10 and 2 nm for Fe-Ti oxide. The crystals in these size ranges were rare. In the present study, we present a theoretical interpretation for these observations by considering decompression-induced crystallization of solid solution minerals in order to investigate the development of undercooling in the course of magma ascent leading to various eruption styles.

In the framework of classical CSD theory, in which straight CSD represents constant nucleation density (N_0) and crystal growth rate (in length, G), two explanations can be applied for steepening of CSD slope: a sudden increase of undercooling and crystallization delay leading to rapid recovering. The constant G can be assumed when the undercooling is constant. If crystallization differentiation of the melt catches up with the increase of the liquidus temperature by decompression, the degree of undercooling is kept constant and thus the kink of CSD slope is not formed. Assuming that N_0 and G are proportional to the degree of undercooling, the kink of CSD requires a sudden change of undercooling. The change from phenocrysts to microlites is usually caused by onset of magma ascent from a magma chamber. The increase of undercooling from the crystallization stage of microlite to that of nanolite may be caused by the rapid decrease of water solubility in melts and resulting sharp increase of the liquidus temperature. When crystallization differentiation of melt does not catch up with the increase of the liquidus temperature, the crystallization delays and the degree of undercooling increases gradually. If such magmas with large undercooling are emplaced in the shallow level, crystal nucleation is facilitated and thus the kink of CSD slope may form.

The gap of CSD requires nucleation pause for a certain period of time in the course of crystallization. This may occur when activation energy for nucleation exceeds undercooling with decreasing water content (Dowty, 1980). The observed gap in the CSD of the Shinmoedake eruption may be caused by accelerating decrease of water solubility in the magmas as they approaches to the surface.

Keywords: nanolite, microlite, decompression, crystallization, undercooling

