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Effect of pre-existing crystals and melt homogeneity on the decompression-induced crystallization of hydrous rhyodacite magma

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Abstract

Decompression-induced crystallization is an important process that controls the behavior of volcanic eruptions because it strongly affects magma rheology and degassing behavior in the shallow parts of volcanic conduits. Several decompression experiments have been performed to understand and model the crystallization processes; however, the effect of superheating (i.e., heating above the liquidus temperature for a definite period of time) before decompression has not been elucidated, despite the proposal of its importance in previous cooling experiments. As the superheating influences the number of pre-existing crystals and melt homogeneity, it is expected to control decompression-induced crystallization. In this study, we investigated the effects of pre-existing crystals and melt homogeneity on crystallization during the decompression of rhyodacitic magma at a temperature of 900 °C. The magma studied herein has a liquidus temperature of ~920 °C. Five starting materials were prepared via heating at different super-liquidus temperatures (940, 970, 1050, and 1300 °C) and a sub-liquidus temperature (900 °C) using an internally heated pressure vessel and a cold-seal pressure vessel, respectively. Decompression experiments using these starting materials were conducted from 130 to 30 MPa at decompression rates of 5, 20, and 100 MPa h^{-1}. When the melt was completely homogenized (at 1050 and 1300 °C), no crystals were formed at 100 MPa h^{-1} and the small amounts of crystals heterogeneously formed along the capsule wall were found at 5 and 20 MPa h^{-1}. At the same decompression rate, the number density of plagioclase formed during decompression increased as the superheating temperature decreased from 970 to 900 °C, despite the higher number densities of pre-existing crystals before decompression in the samples with lower superheating. Such finding indicates that nucleation occurs easily when the number density is initially high. This result is inconsistent with the idea that nucleation occurs when supersaturation is sufficient to overcome the energy barrier for nucleation, and the growth of pre-existing crystals decreases supersaturation. In contrast, the results of our experiments can be explained by considering that higher superheating results in a more homogeneous melt structure with few pre-crystal clusters, which are growth sites, and ultimately the suppression of nucleation. Based on these results, we conclude that pre-existing crystals and melt homogeneity strongly affect the crystal texture formed by decompression. For application to natural systems, the high number density of microlites found in natural samples may be due to heterogeneous nucleation caused by the presence of pre-crystal clusters and other mechanisms. Furthermore, the superheating of magma in a reservoir caused by the injection of high-temperature mafic magma may influence the crystal texture during magma ascent and, hence, control the explosivity of the eruption.

Keywords: Decompression-induced crystallization, superheating, magma decompression, crystal texture