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Crystallization kinetics in magmas during decompression

Fabio Arzilli (1), Mike Burton (1), and Michael R. Carroll (2)

(1) School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, United Kingdom, (2) School of Science and Technology, Geology Division, University of Camerino, Camerino, Italy

Many variables play a role during magma crystallization at depth or in a volcanic conduit, and through experimentally derived constraints we can better understand pre- and syn-eruptive magma crystallization behavior. The thermodynamic properties of magmas have been extensively investigated as a function of T, P, fO_2 and magma composition [1], and this allows estimation of the stability of equilibrium phases and physical parameters (e.g., density, viscosity). However, many natural igneous rocks contain geochemical, mineralogical and textural evidence of disequilibrium, suggesting that magmas frequently follow non-equilibrium, time-dependent pathways that are recorded in the geochemical and petrographic characteristics of the rocks. There are currently no suitable theoretical models capable of calculating nucleation and growth rates in disequilibrium conditions without experimental constraints. The aim of this contribution is provide quantitative data on growth and nucleation rates of feldspar crystals in silicate melts obtained through decompression experiments, in order to determine the magma evolution in pre- and sin-eruptive conditions. Decompression is one of the main processes that induce the crystallization of feldspar during the magma ascent in the volcanic conduit. Decompression experiments have been carried out on trachytic and basaltic melts to investigate crystallization kinetics of feldspar as a function of the effect of the degassing, undercooling and time on nucleation and crystal growth process [2; 3]. Furthermore, feldspar is the main crystals phase present in magmas, and its abundance can strongly vary with small changes in pressure, temperature and water content in the melt, implying appreciable variations in the textures and in the crystallization kinetics.

Crystallization kinetics of trachytic melts show that long experiment durations involve more nucleation events of alkali feldspar than short experiment durations [2]. This is an important aspect to understand magma evolution in the magma chamber and in the conduit, which in turn has strong effects on magma rheology.

The onset of the crystallization process in basaltic melts during experiments was characterized by an initial nucleation event within the first hour of the experiment, which produced the largest amount of plagioclase [3]. This nucleation event, at short experimental duration, can produce a dramatic change in crystal number density and crystal fraction, triggering a significant textural evolution in only 1 h.

The obtained results show that crystallization kinetics are strictly related to undercooling, time, final pressure, superheating and water content in the melt. Here we show that a small decrease in pressure could induce a dramatic increase of crystallinity in few hours, in natural systems this may affect the magma rheology and eruptive dynamics on very short time scales.

References:

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