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The effect of halogens (F, Cl) on the near-liquidus crystallinity of a hydrous trachyte melt

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Abstract

The effect of F and Cl on the liquidus temperature of a hydrous (~3.5–4 wt% H_2O) trachytic melt (~66 wt% SiO_2) at 925 to 990 °C and at 100 MPa has been experimentally investigated. We employed a novel disequilibrium approach involving diffusion couple experiments with the two-diffusion couple end-members differing solely in halogen concentrations. A shift of the liquidus temperature by ~50 °C was observed between a halogen-poor and halogen-enriched melt. Each experiment spanned the entire range of F and Cl concentrations between the two end-member compositions. We determined the halogen concentrations at the transition from crystal-bearing to crystal-free melt. These concentrations correspond to the liquidus halogen concentrations of the melt at each experimental temperature. We demonstrate that there is a limiting halogen concentration (~0.19–0.52 wt% F; ~0.07–0.24 wt% Cl), below which the melt crystallizes spherulitic clinopyroxene during heating to the run temperature. At high temperatures, upon diffusion of F and Cl into the halogen-poor melt, those crystals dissolve, leaving behind a dissolution front parallel to the diffusion interface. We propose that the dissolution is a consequence of F and Cl complexing with some of the main cationic components of clinopyroxene (Mg, Fe, Ca), thereby destabilizing this phase. Thus, the experimental dissolution of clinopyroxene is a manifestation of a liquidus depression caused by increased halogen content. Our results show that the liquidus shifts at a rate of ~1575(379) K/mol% of F and Cl in the melt, which is a minimum estimate, assuming both halogens equally drive dissolution. This liquidus depression is valid for a range of halogen concentrations (~0.06–0.87 wt% F; ~0.06–0.36 wt% Cl) and the experimental temperatures. Our findings illustrate that the degassing of halogens during or prior to an eruption can enhance crystallization in the melt and therefore influence magma physical properties that may ultimately affect eruption style.

Keywords: Halogens, liquidus depression, phase equilibria, diffusion couple, crystal dissolution; Halogens in Planetary Systems