

The fidelity of plagioclase-melt thermometry for decompression-driven magma crystallisation

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Our ability to constrain the temperature and pressure of mineral-melt assemblages in igneous rocks through thermobarometry is fundamental to understanding the conditions of magma storage, fractionation, ascent and eruption. However, if the critical assumption of equilibrium is not tested rigorously, it may lead to significant problems in interpretation. We investigated plagioclase-melt thermometry in hydrous, subduction zone magmas using phase equilibria studies, thermodynamic modelling and natural datasets to assess the controls on the resulting pH_2O -T patterns.

Predicted contours of constant X_{An} in pH_2O -T space (from hydrous to anhydrous) show that calculated temperature (T_{calc}) increases strongly with decreasing H_2O content, with ΔT_{calc} from ~ 150 °C to >400 °C using different thermobarometers. Natural sample suites give T_{calc} that are strongly model-dependent and can vary by >250 °C, especially at low H_2O concentrations.

We calculated suites of data in pH_2O -T space from plagioclase-melt thermometry of melt inclusions and matrix glasses where the composition of the host or equilibrium plagioclase was well constrained. The natural data were for Soufrière Hills, Montserrat; Mount St Helens, USA; Unzen, Japan; Izu Oshima, Japan; and Shiveluch Volcano, Kamchatka. All datasets defined arrays of negative slope in pH_2O - T_{calc} space, which, taken at face value, could be interpreted as significant heating during decompression crystallisation. Regressions indicate that 68-92% of the calculated temperature increase actually results from variations in H_2O content of the glass. In contrast, the anhydrous glass composition typically plays a minor role in controlling T_{calc} , while plagioclase composition is not a significant factor.

Importantly, the plagioclase-melt $K_{\text{D}}(\text{Ab-An})$ varies systematically with pH_2O , melt composition and plagioclase content, and therefore does not seem to be a good criterion for equilibrium. We suggest that the apparent heating effect, seen as high T_{calc} at low H_2O contents, in part actually reflects an increase in the degree of disequilibrium as the 'effective undercooling' increases during decompression crystallisation.