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The validity of plagioclase-melt geothermometry for degassing-driven magma crystallization

Madeleine C.S. Humphreys[1,*], Marie Edmonds[2], and Marthe S. Klöcking[2]

[1]Department of Earth Sciences, Durham University, Science Labs, Durham, DH1 3LE, U.K.
[2]Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ, U.K.

Abstract

Any quantitative interpretation of the formation conditions of igneous rocks requires methods for determining crystallization temperature. Accurate application of such thermobarometers relies on the attainment of equilibrium in the system to be studied. This may be particularly difficult in silicic magmas, where diffusivities are low and crystallization kinetics sluggish. Moreover, progressive degassing of volatile-rich magmas during ascent can result in continuous changes in effective undercooling, causing particular problems in achieving equilibrium between melt and crystals that grow in response to decompression. We consider these problems in the context of plagioclase-melt equilibria for magmas undergoing decompression and degassing-driven crystallization, using two published thermometers. The two thermometers show similar trends with key parameters but absolute temperatures can vary significantly. Analysis of decompression experiments conducted at constant temperature shows systematic variations in calculated temperature and equilibrium constant with varying decompression rate and quench pressure. This indicates that an unrecognized lack of equilibration could result in significant temperature overestimates and potentially spurious results. This highlights the need to assess for equilibrium, and we discuss problems associated with some commonly used indicators of equilibration. Finally, retrospective analysis of published plagioclase-hosted melt inclusion suites from five subduction zone volcanoes shows systematic increases in calculated temperature and decreases in equilibrium constant with decreasing H_2O concentration. While this could represent the signature of latent heat of crystallization, we suggest that such patterns should be treated with caution unless there is clear evidence of sustained equilibrium between plagioclase and melt during decompression.

Keywords: Geothermometry, decompression crystallization, plagioclase, equilibrium, melt inclusions, degassing, Invited Centennial article