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Clinopyroxene-melt experiments of Holuhraun basalt, Iceland: implications for magma storage and transport in the crust

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Estimating depth of magma storage at active volcanoes has proven difficult and different methods appear to yield contradictory results. The large fissure eruption at Holuhraun (29 August 2014 to 27 February 2015), which emitted approximately 1.5 km3 of basalt, was preceded by two weeks of laterally migrating seismicity from the central volcano Bárðarbunga, approximately 40 km away. How the magma was transferred to surface and where it was stored before the eruption is still a matter of debate. Pressure (P) of crystallisation can be derived from petrological geothermobarometers such as clinopyroxene (cpx)-melt equilibrium if the equilibrium composition of both phases can be determined, but with relatively large uncertainties resulting from the calibration of the barometer (e.g. Putirka, 2008). Two types of experiments were performed using Holuhraun basalt as starting material to better understand the behaviour of cpx during transport and storage of an olivine tholeiitic basalt: (i) phase equilibrium experiments from 0.5 GPa to 1 GPa, and from 1130°C to 1270°C; and (ii) decompression experiments in which the basalt powder was first equilibrated at 1 GPa-1240°C, then decompressed to 0.5 GPa-1235°C (adiabatic case) or 0.5 GPa-1190°C (decompression and cooling), and finally maintained at these conditions from 0 to 4 days. These decompression experiments were aimed at simulating the evolution of a cpx-bearing magma being transported from depth to a shallower level, where it resides for some time before being erupted and quenched.
In the phase equilibrium experiments, the pressures and temperatures (T) calculated using equations 30 and 33 of Putirka (2008) agree well with the experimental values, especially near the liquidus ([U+F044]P $\leq \pm$ 0.05 GPa; [U+F044]T $\leq \pm$ 15°C), confirming pre-existing calibration of the cpx-melt thermobarometer. In marked contrast, decompression experiments resulted in major textural and chemical changes. Clinopyroxene was totally dissolved in less than 30 minutes at 0.5 GPa-1235°C (adiabatic pressure release), but only partially dissolved at 0.5 GPa-1190°C. The cpx crystals show anhedral shapes typical of dissolution at the end of the decompression step, but develop planar facets and euhedral shapes with time. After three to four days, the P calculated from euhedral cpx-rim and adjacent melt compositions are close to the final experimental pressure (0.5 GPa), whereas those calculated using the cpx core compositions approach the initial conditions (1 GPa). A textural equilibrium between cpx-rim and melt is thus a prerequisite for obtaining reliable P estimates from the barometer. Finally, the analog experiments show that significant chemical exchanges occur between crystals formed at mid-to-lower crustal level and melt during magma transport to the surface even in the case of a fast ascent, and that these exchanges can skew magma storage pressure calculations.

Putirka, K. 2008, Rev. Mineral. Geochem., 69, 61-120.