Do olivine crystallisation temperatures faithfully record mantle temperature variability?

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Crystallisation temperatures of primitive olivine crystals have been widely used as both a proxy for, or an intermediate step in calculating, mantle temperatures. The olivine-spinel aluminium-exchange thermometer has been applied to many samples from mid-ocean ridges, ocean islands and large igneous provinces, yielding considerable variability in primitive olivine crystallisation temperatures. We supplement the existing data with new crystallisation temperature estimates for Hawaii, in the range $1282\pm21 - 1375\pm19^\circ C$.

Magmatic temperatures may be linked to mantle temperatures if the thermal changes during melting can be quantified. Melting lowers the temperature of co-existing magma and solid mantle, owing to the latent heat of melting. The magnitude of this cooling depends on melt fraction, itself controlled by mantle temperature, mantle lithology and lithosphere thickness. All of these parameters are likely to vary both spatially and temporally. For robust quantification of mantle temperature variability, the controls of lithosphere thickness and mantle lithology on crystallisation temperatures must be isolated.

We develop a multi-lithology melting model that can predict crystallisation temperature. The model allows mantle temperature, lithospheric thickness, and fractions of mantle lherzolite, pyroxenite and harzburgite to be varied. Inverting the model using a Bayesian Monte Carlo routine enables assessment of the extent to which crystallisation temperatures require variations in mantle temperature. We find that the high crystallisation temperatures seen at mantle plume localities do require high mantle temperatures. However, in the absence of further constraints on mantle lithology or melt productivity, we cannot robustly infer variable plume temperatures in either the present-day or throughout the phanerozoic. This work demonstrates the limit of petrological thermometers when other geodynamic parameters are poorly known.