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# The impact of temperature variations on diffusion-derived timescales of magmatic processes from diffusion chronometry

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Diffusion chronometry is widely used to investigate magmatic processes such as magma mixing, recharge and storage by modelling chemical zoning in minerals. Zoning patterns preserved in crystals can record thermal conditions and perturbations within magmatic systems and the progressive smoothing of these gradients through diffusion provides a quantitative means of constraining associated timescales.

Most applications assume diffusion occurs under constant temperature conditions, an approximation that facilitates analytical treatment. However, magmatic systems commonly experience some degree of thermal evolution during ascent, storage or emplacement. Given the strong temperature dependence of diffusion rates, even moderate variations in temperature may influence the cumulative extent of diffusive re-equilibration. Differences in activation energy may also produce distinct inter-element variations. As a result, assuming strictly isothermal conditions may affect inferred durations, particularly where independent thermal constraints are limited.

Here we present a Monte Carlo–based modelling framework to explore the influence of time-dependent temperature evolution on diffusion profiles in plagioclase. Rather than prescribing a single thermal scenario, we use the variation of anorthite content to constrain the variation of temperature across diffusion profiles and generates families of thermal histories that best explain the diffusion profiles. Diffusion is evaluated along each history to produce corresponding zoning profiles, which are then compared to reference profiles to assess parameter trade-offs and uncertainty. By retaining a subset of the best-fitting Monte Carlo realisations, we evaluate the range of thermal histories capable of reproducing a given diffusion profile. This provides a flexible framework capable of accommodating alternative thermal evolutions and testing how modelling assumptions influence inferred timescales.

We will present results on diffusion profiles collected in plagioclase crystals from a number of different magmatic systems as an example. The results suggest that estimating timescales from diffusion profiles without accounting for temperature sensitivity in the modelling framework may influence significantly the estimated durations.