Accurate and precise timescales from olivine diffusion-modeling: a 3D perspective

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Nearly all current applications of diffusion modeling employ 1D chemical transects performed across 2D sections of a given set of crystals. To date, however, the accuracy and precision with which timescales can be retrieved from randomly intersecting olivine populations within a rock sample have not been examined in detail.

Three-dimensional numerical olivines with various shapes/habits (spherical, rectangular parallelepiped, and polyhedral) were generated and left to diffuse at magmatic temperatures for a certain duration using a finite-difference scheme. To further simulate realistic conditions, the models incorporated diffusion anisotropy (D faster along the c-axis), and the presence or absence of compositional plateaus in the olivine cores. These olivines were then sectioned either (1) through their cores or (2) at random distances from their center, and either (3) along the a, b or c crystallographic axes or along random orientations. Finally, to cover a range of natural magmatic scenarios the simulations tested six various forsterite zoning configurations (normal, reverse, core-rim with different compositions). Results show that timescales retrieved from 1D profiles are highly inaccurate if diffusion anisotropy is not taken into account. Even when anisotropy is corrected for, timescales can still vary between 0.2-10 times the true 3D diffusion time due to crystal shape and sectioning effects (e.g. Figure 1). We describe simple grain selection procedures for reducing the misfit between calculated and actual diffusion times, to achieve estimated uncertainties of ~20% relative.

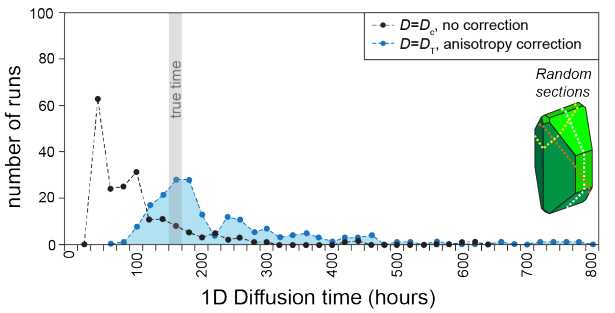

Figure 1: Distribution of times resulting from two hundred 1D diffusion models performed along a randomly-sectioned 3D olivine crystal. For each simulation, the times are calculated by fitting a 1D diffusion model to a profile obtained along a given direction in a 3D crystal, for which the true diffusion time is known.