



## **Effects of 3 dimensional crystal geometry and orientation on 1D and 2D time-scale determinations of magmatic processes using olivine and orthopyroxene**

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One of the achievements in recent years in volcanology is the determination of time-scales of magmatic processes via diffusion in minerals and its addition to the petrologists' and volcanologists' toolbox. The method typically requires one-dimensional modeling of randomly cut crystals from two-dimensional thin sections. Here we address the question whether using 1D (traverse) or 2D (surface) datasets exploited from randomly cut 3D crystals introduces a bias or dispersion in the time-scales estimated, and how this error can be improved or eliminated.

Computational simulations were performed using a concentration-dependent, finite-difference solution to the diffusion equation in 3D. The starting numerical models involved simple geometries (spheres, parallelepipeds), Mg/Fe zoning patterns (either normal or reverse), and isotropic diffusion coefficients. Subsequent models progressively incorporated more complexity, 3D olivines possessing representative polyhedral morphologies, diffusion anisotropy along the different crystallographic axes, and more intricate core-rim zoning patterns. Sections and profiles used to compare 1, 2 and 3D diffusion models were selected to be (1) parallel to the crystal axes, (2) randomly oriented but passing through the olivine center, or (3) randomly oriented and sectioned. Results show that time-scales estimated on randomly cut traverses (1D) or surfaces (2D) can be widely distributed around the actual durations of 3D diffusion ( $\sim 0.2$  to 10 times the true diffusion time). The magnitude over- or underestimations of duration are a complex combination of the geometry of the crystal, the zoning pattern, the orientation of the cuts with respect to the crystallographic axes, and the degree of diffusion anisotropy. Errors on estimated time-scales retrieved from such models may thus be significant. Drastic reductions in the uncertainty of calculated diffusion times can be obtained by following some simple guidelines during the course of data collection (i.e. selection of crystals and concentration profiles, acquisition of crystallographic orientation data), thus allowing derivation of robust time-scales.