American Mineralogist, Volume 100, pages 2026–2042, 2015

SPECIAL COLLECTION: OLIVINE

Accuracy of timescales retrieved from diffusion modeling in olivine: A 3D perspective†

THOMAS SHEA[1,]*, FIDEL COSTA[2], DANIEL KRIMER[2] AND JULIA EVE HAMMER[1]

[1]Geology and Geophysics, SOEST, University of Hawaii, Honolulu, Hawaii 96822, U.S.A.
[2]Earth Observatory of Singapore, Nanyang Technological University, 639798, Singapore

ABSTRACT

Diffusion modeling in olivine is a useful tool to resolve the timescales of various magmatic processes. Practical olivine geospeedometry applications employ 1D chemical transects across sections that are randomly sampled from a given 3D crystal population, but the accuracy and precision with which timescales can be retrieved from this procedure are not well constrained. Here, we use numerical 3D diffusion models of Fe-Mg to evaluate and quantify the uncertainties associated with their 1D counterparts. The 3D diffusion models were built using both simple and realistic olivine morphologies, and incorporate diffusion anisotropy as well as different zoning styles. The 3D model crystals were sectioned along ideal or random planes, which were used to perform 1D models and timescale comparisons. Results show that the timescales retrieved from 1D profiles are highly inaccurate and can vary by factors of 0.1–25 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. Simple grain selection procedures are described to reduce the misfit between calculated and actual diffusion times, and achieve an accuracy and precision of ~5% and ~15–25% relative, respectively. Provided that the grains are carefully selected, about 20 concentration profiles and associated 1D models suffice to achieve this accuracy.

Keywords: Olivine, geospeedometry, diffusion modeling, numerical modeling, crystal morphology, random sectioning