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Probe the Probe, Test the Clock: A Round Robin Assessment of EPMA Variability and Olivine Diffusion Timescales

SARAH C SHI[1], PENNY WIESER[2], MATTHEW L. M. GLEESON[3], EUAN J. F. MUTCH[4], DANIEL LEE[5], TERRY PLANK[5], KENDRA J. LYNN[6], DAWN RUTH[7], ADRIEN MOUREY[4], WILLIAM HENRY TOWBIN[5], CELINE MARTIN[8], LOWELL R MOORE[9], HERVÉ REZEAU[10], SLOANE A KENNEDY[11], FRANK TEPLEY III[11], CHIARA MARIA PETRONE[12] AND ANETTE VON DER HANDT[13]

[1]UC Berkeley
[2]University of California, Berkeley
[3]University of California Berkeley
[4]Nanyang Technological University
[5]Lamont-Doherty Earth Observatory, Columbia University
[6]USGS Hawaiian Volcano Observatory
[7]USGS
[8]American Museum of Natural History
[9]Department of Geosciences, Virginia Tech
[10]MIT
[11]Oregon State University
[12]Natural History Museum
[13]University of British Columbia

Diffusion chronometry provides powerful constraints on timescales of pre- and syn-eruptive magmatic processes, including magma storage, mixing, and ascent. The reliability and uncertainty of these calculated timescales depend on 1) the precision and accuracy of microanalytical characterization of chemical gradients in minerals, 2) the estimated P-T-fO_2 conditions, and 3) the numerical modeling framework and modeling decisions used. Despite widespread application of diffusion chronometry in volcanic systems, the reproducibility of measured values across laboratories and timescale estimates across numerical approaches has not been systematically evaluated.

We present results from a two-part round robin study to quantify variability through the diffusion chronometry workflow, from microanalysis to numerical modeling. First, we conducted a microanalytical round robin analyzing a suite of twenty-four glass and mineral standards—including olivines, pyroxenes, feldspars, hornblendes, oxides—across laboratories and instruments. For olivine standards, measurements from different laboratories differ by up to ~1 forsterite unit depending on calibration strategy and primary standard selection. Using the Dohmen and Chakraborty (2007) parameterization, this corresponds to a ~7% difference in $D_{Fe\text{-}Mg}$, providing a baseline for how analytical uncertainty propagates forth to diffusion studies. Whilst wavelength-dispersive spectroscopy on electron probe microanalyzers (EPMA) has traditionally been the standard for quantitative mineral analysis, we demonstrate that standards-based SEM-EDS measurements can achieve comparable accuracy and precision for major element compositions.

Second, we initiated a diffusion chronometry round robin for Fe-Mg diffusion in olivine to evaluate resultant timescales and uncertainties between modeling frameworks. Participants were first tasked with calculating parameters (fO_2 and $D_{Fe\text{-}Mg}$) for a set of given conditions (T, P, buffer, forsterite, crystallographic orientation). Identical chemical zoning profiles were distributed, with participants asked to either model diffusion using predetermined step positions and initial core-and-rim concentrations, or by providing trace element zoning data and allowing free selection of initial conditions. By comparing the calculated parameters (fO_2, $D_{Fe\text{-}Mg}$, calculated timescales), we can identify the origin of differences between models. Using our round robin, we also assess the influence of analytical variability on calculated results. Overall, this coordinated community effort provides the first benchmark of timescales and inter-user and inter-model variability obtained from the same profiles in diffusion chronometry.