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The Kīlauea Iki lava lake: a 30-year long diffusion experiment to study the re-equilibration of olivine in natural basalt

NABILA NIZAM[1], TOM SHEA[2] AND ROSALIND L. HELZ[3]

[1]University of Hawai‘i at Mānoa
[2]University of Hawai'i at Mānoa
[3]US Geological Survey
Presenting Author: nizam@hawaii.edu

Petrological and chemical analysis of igneous minerals can be used to reconstruct the plumbing system of a magmatic body, and to determine the timing of subsurface events such as magma recharge and/or mixing. During these events, sudden disequilibrium can lead to important compositional changes that are recorded in the mineral zoning record. Diffusion of elements within crystals creates chemical gradients that can be used to extract time information using diffusion chronometry [1]. However, this technique requires robust knowledge of initial and final zoning in the crystal and constraints on the diffusivities of the elements.

In this study, we leverage a multi-decadal, natural 'diffusion experiment' to investigate the diffusive re-equilibration of entire olivine populations. We use drill core samples collected from the Kīlauea Iki lava lake over the span of 29 years (1959-1988) as the lava lake cooled down. Previous microprobe analyses and MgO thermometry of matrix glasses from the scoria of 1959 eruption showed maximum temperature ~1220°C and 20 years later in 1979, the maximum temperature from a drill core was ~1140°C [2]. Using petrographic and electron probe micro-analyzer (EPMA) analysis, we examine core-rim variations in major (Fe-Mg) as well as minor and trace elements (Ca, Ni, Mn, P, Al, and Cr). This allows us to observe and track the changes in zoning within the entire olivine population, thus providing insight into the diffusivities of these elements in a natural setting.

By studying the homogenization of the olivine cores at the scale of the whole population over time and exploiting elements with varying diffusivities, we can identify elements that best record time information, and those that may show more complex behavior (e.g., element coupling, major element-dependent partitioning). These samples offer a unique opportunity to strain test diffusion chronometry for olivine with well-defined temperature-time paths over multidecadal periods.

[1] Costa et al. (2020), *Nature Reviews Earth & Environment 1, 201-214*

[2] Helz (2020), *U.S. Geological Survey Open-File Report 2020–1012*