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Magma mobilization timescales preceding the 1997 eruption of Okmok Volcano, Alaska: Insights from crystal cluster petrography and diffusion modeling

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Mount Okmok is an active, high threat shield volcano located in the Alaska-Aleutian arc, historically producing eruptions that have impacted climate, aviation, and local communities. The most recent phreatomagmatic eruption (VEI 4) of Okmok in 2008 produced ash plumes reaching up to 16 km and was preceded by only an hour of precursory seismicity, suggesting Okmok can give minimal warning of impending eruptive activity [1]. Here we investigate whether Okmok's crystal cargo records timescales of magma mobilization in the weeks to months leading to eruption to better interpret monitoring signals. We assess this through the lens of the 1997 Strombolian eruption (VEI 3) of Okmok, using a novel approach of multiphase crystal cluster analyses paired with elemental (Fe-Mg) diffusion modeling in olivine and pyroxene. This multi-faceted approach allows us to not only determine the timescales of magma mobilization recorded by the crystals, but to also pinpoint the exact processes (e.g., recharge, ascent-driven decompression) leading to mobilization [2].

Petrographic analysis of the 1997 eruption reveals very crystal-rich material containing numerous multiphase crystal clusters. Preliminary elemental data were collected using a field emission scanning electron microscope with backscattered electron (BSE) imaging, allowing for a qualitative assessment of the composition of and zonation within identified crystal clusters (Figure 1). Based on BSE images, crystal clusters with suitable, shared zonation were then targeted for further quantitative analyses of Fe-Mg concentrations by electron microprobe (EMP). Using an adapted MATLAB-based Bayesian diffusion code [3], Fe-Mg diffusion profiles within olivine and pyroxene will be modeled to extract timescales of magma mobilization using respective diffusion coefficients. Ultimately, the results of this work will inform whether Okmok's eruption run-up timescales may be longer than inferred from short-duration geophysical precursors, and can aid in future monitoring and hazard mitigation efforts at the volcano.

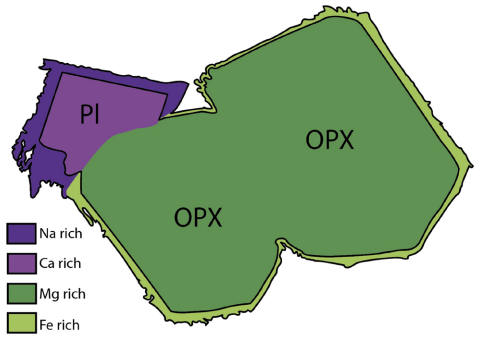


Figure 1. A schematic of a scanning electron microscope backscattered electron image, showing clear shared zonation between plagioclase (Pl) and orthopyroxene (OPX) in a crystal cluster from 1997 sample 01-NYO-05.

[1] Larsen et al. (2013). J. Volcanol. Geotherm. Res.
[2] Moshrefzadeh et al. (2023). J. Volcanol. Geotherm. Res.
[3] Lynn et al. (2024). Nat. Commun.