

Chemical fingerprints and residence times of olivine in the 1959 Kilauea Iki eruption, Hawaii: Insights into picrite formation

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ABSTRACT

Olivine-rich mafic volcanic rocks (picrites) are a common and important part of ocean island and flood basalt volcanism. Despite their primitive bulk compositions (high MgO, FeO, Mg#, and low SiO₂), olivine-rich magmas are typically interpreted as the result of the addition of olivine from cumulate zones into more evolved basaltic liquids (MgO \leq ~8 wt%). There are commonly two texturally distinct olivine populations in picrites: type 1 grains with planar dislocation (kink) bands, subgrains, or undulose extinction; and type 2 grains that lack these optical textures. Type 1 olivine is similar in texture to olivine from tectonized ultramafic rocks, suggesting that these textures result from plastic deformation, likely within cumulate zones. However, recently it has been proposed that type 1 olivine could also result from growth phenomena or crystal-crystal collisions. In the Kilauea Iki picrite samples used in this study, type 1 grains make up only 10–20% of the modal olivine; however they make up 30–65% of the total olivine by volume due to their large size. Therefore, type 1 grains make a large contribution to the overall composition of Kilauea Iki picrites. A combination of textural (optical defects, crystal size distributions, and minor element zoning) and geochemical analyses (trace element concentrations and diffusion of minor elements) suggests that type 1 and type 2 olivine grains have experienced distinctly different petrological histories and that they are antecrysts and autocrysts, respectively. Differences between type 1 and type 2 olivine are evident in the abundances of slow diffusing trace elements (Al, P, Ti, V), which are likely inherited from their distinct parent magmas. Type 1 and type 2 grains also define different slopes in crystal size distributions, and constraints from diffusion of P and Cr suggest that type 1 grains have longer magmatic residence times than type 2 grains. Type 1 grains likely derive from deformed cumulates within the plumbing system of Kilauea volcano, and our work supports the hypothesis that picrites from Kilauea Iki are formed by the accumulation of antecrystic olivine in more evolved basaltic liquid. Our work further supports models that type 1 olivine textures are formed during plastic deformation within cumulate zones and are not the result of growth phenomena. Our methods can be applied to other olivine-rich volcanic rocks to test the cumulate model for the formation of type 1 olivine textures, which are relatively common in picritic and related rocks from other settings.

Keywords: Kilauea Iki, olivine, picrite, diffusion, crystal size distribution, olivine cumulate