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Insights into processes of magma mixing and transport at Kīlauea using time-series scoria samples vs. the tephra deposit

ROSALIND L. HELZ[1] AND KENDRA J. LYNN[2]

[1]US Geological Survey

[2]USGS Hawaiian Volcano Observatory

Presenting Author: rozhelz@gmail.com

The 1959 summit eruption of Kīlauea Volcano offers a unique look at magmatic processes within Kīlauea's plumbing because (1) it has a large, complex cargo of olivine, (2) its two magmatic components differ enough chemically to be trackable, and (3) there are both a suite of scoria samples collected in real time during the eruption, and samples collected later from the tephra deposit.

Melt compositions in the real-time samples show that the November scoriae were thermally and chemically distinct, whereas the December 1959 scoriae were thermally more uniform and better-mixed. Although later scoria samples contain more lava drainback (areas of lower-MgO melt within more magnesian melt), the dominant melt remained at 8-9 wt % MgO to the end of the eruption. Most glasses in the ejecta have MgO ≤ 7.5 wt %, suggesting late-stage olivine overgrowth relative to real-time samples.

The scoriae and fall deposits contain abundant olivine, and olivine phenocryst cores are compositionally bimodal in both suites. The range of olivine compositions next to melt changes from Fo_{84-88} in early scoriae to Fo_{84-85} in the latest samples, as equilibration proceeds. Less forsteritic rims occur only in contact with drainback bodies in the scoriae, whereas in the fall deposits rims commonly extend to Fo_{80-81}, consistent with their observed glass compositions.

Diffusion calculations based on olivine major element (Fo) zoning show that the sample groups yield different patterns of timescales. Real-time scoria and some fall deposit olivines record two entrainment events that correspond to resumption of summit inflation (mid-August) and accelerated inflation (mid-October) prior to the 1959 eruption. Coarse non-zoned olivine reflects steady-state melt migration and olivine crystallization, while sparse longer times show that erasure of olivine zoning occurs even during periods of background melt rise. Another subset of olivine, dominated by the smaller crystals in the ejecta blanket, yield syneruptive diffusion timescales. The melt and olivine data demonstrate that studies of real-time pyroclasts can yield information not accessible by studying the eruption's fall deposit alone.