Hybrid Olivine Phenocryst Populations in the 1959 Kīlauea Eruption and Constraints on Their Time of Arrival in the Summit Reservoir

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Lavas of the 1959 summit eruption of Kīlauea Volcano contain 15.43 weight % MgO on average. Continuous sampling during the eruption (14 Nov. – 21 Dec.) found that samples with high MgO (16.5-19.5 wt. %) were erupted either between 18-19 November or between 5-19 December. The November samples contain 20-25 wt. % olivine in melt with 10 wt. % MgO. Olivine crystals in these and later phase 1 samples are unzoned or reversely zoned, while olivine in the later olivine-rich samples show normal zoning, consistent with progressive equilibration with shallower, stored magma. Thus the entire olivine load seems to have been delivered to the summit reservoir on 18-19 November.

The olivines are conspicuously heterogeneous: large, blocky deformed crystals and crystals with swarms of sulfide-bearing melt inclusions, both antecrystic, make up 20-25% of the olivine load. The euhedral olivine phenocrysts (>1 mm long) are chemically heterogeneous, consisting of ~80% forsteritic olivine ($Fo_{86.5-88.0}$) and 20% of more Fe-rich olivine (Fo_{84-86}). The latter compositions are expected for olivine crystallizing from the stored magma (melt MgO = 8-9 wt. %). Subtracting these subpopulations from 20-25 % bulk olivine leaves 15-16 % olivine as potentially phenocrystic to the melts with MgO = 10 wt. %.

Equilibrium crystallization calculations for bulk compositions with 11.5-12.2 wt. % MgO (using MELTS) show that 3-4 wt. % olivine will have crystallized at the point where melt MgO = 10.0%, and that the bulk olivine is ~Fo_{86}. At higher bulk MgO contents, more olivine can crystallize: an initial melt with 14.5% MgO would crystallize 7-8 wt. % olivine when melt MgO = wt. 10 %. This is half the euhedral olivine that remains to be accounted for in the olivine-rich samples; thus even this subpopulation is derived from two or more melts.

Although the 1959 olivine population is varied, CO_2 contents in melt inclusions are low and show little variation. Compositional mapping shows that simple euhedral olivine crystals have complex growth histories, with gradual infilling of forsteritic skeletal frameworks. The pervasive low CO_2 contents suggest that sealing of melt inclusions is a late process, triggered by sudden undercooling of the high-MgO liquids when they first reached the summit reservoir.