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Constraints on crystallization of basaltic magma: observations from Kilauea Iki lava lake, Hawaii

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Kilauea Iki lava lake is a picritic (average MgO = 15.5%) magma body, approximately 135 m thick, which underwent extensive internal differentiation as it cooled and crystallized from its formation during the eruption of 1959 until final solidification in the mid-nineties. Observations of its initial state include data on the stages of filling of the lava lake, plus the sequence and temperature of lava compositions erupted. Drilling and core recovery (from 1960 to 1988) have documented the state of the lake at specific times, showing that the rate of growth of the upper crust was nearly linear (∼2.5 m per year between 1962 and 1979), and that the overall pattern of cooling of the lava lake is consistent with conductive heat loss. Recovery and analysis of partially molten drill core has provided a detailed view of the cooling and differentiation history of the melts and minerals within the lake.

Observations that may be relevant to older systems include: (1) documentation of when and to what extent olivine settling occurred in the lake; (2) the observation that the most differentiated part of the lake, which lies within the upper crust at a depth of 20-40 m, had completely crystallized by 1975, and (3) the observation that the position of the last interstitial melt was at 80-85 m down, or 62% of the way down in the lake, as would be predicted from conductive cooling. The lava lake lost heat through its roof faster than through the floor, with the result that the position of most-differentiated horizon is grossly offset from the position of the final melt.

Circulation patterns in Kilauea Iki were initially driven by lava input during the eruption plus extensive loss of volatiles. These processes significantly affected the location of foundered crust within the lake, as well as the accumulation of coarse, pre-existing olivine phenocrysts between 50 and 95 m. Subsequently, two other major differentiation processes within the lake were driven by upward movement of low-density melts (compositional convection) or of vesicle plumes + melts. These two processes operated vertically, with large-scale motion perpendicular to the (sub-horizontal) isothermal surfaces in the crystallizing mush zones. They have also influenced the grainsize of groundmass minerals throughout the lake. These processes, together with limited olivine settling, have created the existing chemically zoned body. Because of the real-time constraints on when and by what processes the differentiated body that now exists at Kilauea Iki was produced, we can begin to better understand other, older lava lakes and sills, where only the final state is available to us.