Using zoned melt inclusions to quantify eruptive cooling rates on Hawaii

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Glassy olivine-hosted melt inclusions are compositionally zoned, and modelling the development of diffusive gradients across melt inclusions during cooling can be used to quantify timescales of eruption [1]. We conducted a series of homogenization and controlled cooling-rate experiments on olivine-hosted melt inclusions from Mauna Loa to characterize the development of compositional zoning during cooling. All of the melt inclusions are zoned due to olivine crystallization on the inclusion wall and diffusive exchange between the boundary layer adjacent to the growing olivine and the inclusion centers. Experimentally cooled and natural inclusions are characterized by lower MgO and FeO and higher SiO_2, Al_2O_3 (and other olivine incompatible oxides) near the inclusion wall relative to the inclusion center. The experiments confirm that on eruptive timescales, the compositions at the centers of inclusions are susceptible to modification by diffusion, particularly for small inclusions and those subjected to low cooling rates.

MgO profiles from both experimentally cooled and natural unheated inclusions from Hawaii were fit with a diffusion model by varying the cooling rate parameter. The cooling rates that resulted in the best fit models were typically with ±10% of the imposed experimental cooling rates, which ranged from ~70 to ~50,000 °C/hr. MgO profiles from natural olivine-hosted melt inclusions from Papakolea, Hawaii (Mauna Loa) yielded two inclusion populations: rapidly cooled (7500 – 11,800 °C/hr) and slowly cooled (51 – 854 °C/hr), consistent with the olivine beach sands being derived from both olivine-bearing ash beds and basalt flows [2]. Cooling rates calculated using olivine-hosted melt inclusions from the fire-fountaining stage of Kilauea Iki gave uniformly high cooling rates of 5100 – 8800 °C/hr, consistent with rapid quenching of tephra in air.

CaO profiles in melt inclusions are anomalous and are a dominated by multicomponent diffusion in the liquid. We show that the shape of the CaO profile can be used roughly to order inclusions by cooling rate.

[1] Newcombe *et al.* (2014) *CMP* **168** 1-26. [2] Walker (1992) *Pacific Science* **46** 1-10.