Crystal scavenging from mush piles produces spurious melt inclusion records

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The utility of melt inclusions is well established in igneous petrology and volcanology. Olivine-hosted melt inclusions are commonly analysed to investigate pre-eruptive processes and conditions in basaltic volcanic systems, including magma storage depths, magma mixing, and the factors controlling eruption style. However, these studies rely on the assumption that melt inclusions and matrix glasses, the solidified 'carrier' melt, are related, such that the former provides a record of the pre-eruptive storage and evolution of the latter. Here, we show that primitive olivine crystal cargoes and their melt inclusions display significant major and trace element disequilibrium with their carrier melts at Kīlauea Volcano, Hawai`i.

Melt inclusions from any single eruption exhibit diversity in trace element ratios (e.g. Nb/Y) that is comparable to that observed in erupted lava compositions spanning 350 kyr. Within this range, however, there is no obvious eruption-by-eruption correspondence between inclusion compositions and the carrier liquids. This feature suggests that erupting liquids scavenge primitive crystal cargoes from mush piles accumulating diverse melt inclusion populations over centuries to millenia. The narrow compositional range of olivine forsterite contents in many eruptions is also suggestive of prolonged mush pile storage (allowing diffusive re-equilibration of Fe-Mg).

Entrainment of primitive olivines into more evolved melts prior to eruption causes crystallization on the inclusion walls and the sequestration of CO_2 into vapour bubbles. PEC-driven vapour bubble formation can explain the lack of correlation between forsterite content and CO_2 contents at Kīlauea. For example, 70% of olivines with >Fo_{84} record pressures lower than more evolved olivines (<Fo_{84}). This mechanism is particularly problematic at Kīlauea, where the absence of clinopyroxene and plagioclase in most erupted lavas preclude the use of other petrological barometers.

Magmatic systems are increasingly being viewed as mush dominated, with settled crystals forming extensive cumulate piles within the crust. Thus, spurious melt inclusion records similar to those found at Kīlauea are likely present in a wide range of volcanic settings.