PETROLOGIC CHRONOLOGY OF THE 1999 SUB-PLINIAN ERUPTION OF SHISHALDIN VOLCANO

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On April 19, 1999 Shishaldin volcano burst to life, ejecting over 43 million cubic meters of basaltic ash into the atmosphere in a sub-Plinian eruption. InSAR images reveal a surprising lack of deformation preceding or accompanying the VEI 3 eruption (Moran et al., 2006 JVGR). Here we study olivine from this eruption to constrain subsurface magma movements and explore the causes of this unusual behavior. One possibility is that deep (>10 km) magma ascends relatively rapidly (i.e., within months) to shallow depths just prior to eruption (Moran et al., 2006 JVGR). This interpretation is consistent with the onset of long period seismic events suggesting the initiation of upward magma migration from depths of >15 km as early as July of 1998 (Moran et al., 2002 BV). By early February of 1999, at least some magma had reached the near-surface, as evidenced by a remotely-sensed thermal anomaly in the summit crater and vigorous steam venting. We can test the proposed open-vent behavior by determining precise locations of magmas and timing of pre-eruptive magmatic events (e.g., mixing) through petrologic analysis. This will serve both to inform our interpretation of precursory signals used to evaluate volcanic risks and aid in our understanding of open-vent volcanism.

We investigate chemical zonation and melt inclusions in olivines from the 1999 ash. Olivine core compositions are bimodal, with a broad mode centered on Fo_{62} and a much smaller mode of more primitive compositions near Fo_{78}. Most low-Fo olivines are reversely zoned, whereas high-Fo olivine are normally zoned, which provides strong evidence of magma mixing. The mixing-to-eruption timescale can be recovered from chemical gradients frozen in crystals that are erupted during partial diffusive equilibration, following a mixing event. Preliminary results of diffusion modeling suggest mixing occurred months to days prior to eruption. Such a large range of timescales implies that recharge did not occur at a single point in time, rather it was a prolonged event, which is consistent with seismic observations. Spatial constraints for this process can be provided by the study of melt inclusions, which act as pressure gauges because the dissolved volatile contents recorded by inclusions are strongly dependent on the pressures of entrapment. The majority of inclusions are found within the cores of low-Fo olivines. These inclusions have low volatile contents (0.2-2.1 wt.% H_2O, 0-164 ppm CO_2) and lack vapor bubbles. Vapor saturation pressures suggest maximum entrapment depths of 2.7 km, meaning the bulk of the more evolved mixing endmember was located within the edifice of Shishaldin. A second population of melt inclusions are entrapped within the reversely zoned rims of low-Fo olivine. These inclusions have higher volatile contents (0.6-2.4 wt.% H_2O, 199-330 ppm CO_2) and contain vapor bubbles. Entrapment occurred at depths of at least 3.5 km, which is likely to be consistent (after accounting for vapor bubbles) with the maximum depth of volcanic tremor at 5-6 km that occurred in the month leading up to the eruption (Thompson et al., 2002 BV). Thus, olivines record a rich history of the eruption that may relate closely to geophysical observations and bear on the causes of open-vent volcanism.