WHEN DOES ERUPTION RUN-UP BEGIN? MULTIDISCIPLINARY INSIGHT FROM THE 1999 ERUPTION OF SHISHALDIN VOLCANO

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During the run-up to eruption, volcanoes often show geophysically detectable signs of unrest. However, there are long-standing challenges in interpreting the signals and evaluating the likelihood of eruption, especially during the early stages of volcanic unrest. Considerable insight can be gained from combined geochemical and geophysical studies. Here we take such an approach to better understand the beginning of eruption run-up, viewed through the lens of the 1999 sub-Plinian basaltic eruption of Shishaldin volcano, Alaska. The eruption is of interest due to its lack of observed deformation and its apparent long run-up time (9 months), following a deep long-period earthquake swarm. We evaluate the nature and timing of recharge by examining the composition of 138 olivine macrocrysts and 53 olivine-hosted melt inclusions and through shear-wave splitting analysis of regional earthquakes. Magma mixing is recorded in three crystal populations: a dominant population of evolved olivines ($Fo_{60\text{-}69}$) that are mostly reversely zoned, an intermediate population ($Fo_{69\text{-}76}$) with mixed zonation, and a small population of normally zoned more primitive olivines ($Fo_{76\text{-}80}$). Mixing-to-eruption timescales are obtained through modeling of Fe-Mg interdiffusion in 78 olivines. The large number of resultant timescales provides a thorough record of mixing, demonstrating at least three mixing events: a minor event ~9 months prior to eruption, coincident with the onset of deep long-period seismicity; a major event ~50 days before eruption, coincident with a large (M5.2) shallow earthquake; and a final event about a week prior to eruption. Shear-wave splitting analysis shows a change in the orientation of the local stress field about a month after the deep long-period swarm and around the time of the M5.2 event. Earthquake depths and vapor saturation pressures of Raman-reconstructed melt inclusions indicate that the recharge magma originated from depths of at least 20 km, and that mixing with a shallow magma or olivine cumulates occurred in or just below the edifice (<3 km depth). Prior to eruption magma was stored over a large range of depths (~0-2.5 km below the summit), suggesting a vertical reservoir that could explain the lack of detectable deformation. The earliest sign of unrest (deep long-period seismicity) coincides temporally magmatic activity (magma mixing and a change in the local stress state), possibly indicating the beginning of eruption run-up. The more immediate run-up began with the major recharge event ~50 days prior to eruption, after which the signs of unrest became continuous. This timescale is long compared to the seismic run-up to other basaltic eruptions (typically hours to days). Other volcanoes classified as open-system, based on their lack of precursory deformation, also tend to have relatively long run-up durations, which may be related to the time required to fill the shallow reservoir with magmas sourced from greater depth.