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Volatile degassing during fire fountain eruptions on the Moon

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Fire fountain eruptions on the lunar surface represent a fascinating phenomenon that underscores the Moon's geologically active past. These explosive eruptions produced pyroclastic deposits that sometimes appear to be even darker than the mare due to extremely low albedo, such as the "dark mantle deposits" located near Mare Sinus Aestuum and Mare Vaporum.

The Apollo missions returned samples of pyroclastic deposits that contain characteristic volcanic glass beads produced by fire fountain eruptions. Type examples include the "green glass clods" in 15426 and the orange glass soil 74220. However, volcanic glass beads have been identified in samples from all Apollo missions. These volcanic glass beads have been known to be rich in volatiles since their initial return to Earth in the 1970s, with surface correlated volatiles such as Cu, Zn, Pb, S, and Cl.

More recently, detection of tens of ppm of H_2O in volcanic glass beads and >1000 ppm H_2O in olivine-hosted melt inclusions from 74220 brought lunar pyroclastic deposits to the forefront again for understanding the indigenous water content of the lunar mantle, which is crucial for the origin of the Moon. Despite the exciting new discoveries related to the lunar fire fountain eruption products, the mechanism and time scale for lunar fire fountain eruptions remain poorly understood.

In this work, we focus on gaining a better understanding of the degassing history of fire fountain eruptions by evaluating the H_2O, F, Cl, and S concentrations in olivine-hosted melt inclusions, melt embayments, and volcanic glass beads from sample 74220. These specimens show evidence for two stages of degassing during the upwelling of the magma and the explosive eruption following fragmentation. Kinetic modeling shows that time scales ranging from 1,500 to 30,000 seconds are required to explain the diffusive loss of volatiles in melt embayments and orange glass beads from sample 74220, which challenges our current understanding of lunar fire fountain eruptions.