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Prolonged cooling and degassing of pyroclastic deposits on the lunar surface

PENG NI[1] AND YANG ZHAN[2]

[1]University of California, Los Angeles
[2]The Chinese University of Hong Kong

The timing and extent of lunar volcanism provide critical information on the thermochemical evolution of the Moon's interior. In addition to effusive eruptions that filled the dark maria, fire fountain eruptions represent another major style of lunar basaltic volcanism. Samples returned by the Apollo missions show that these pyroclastic deposits contain abundant volcanic glass beads that vary in color from green to yellow, orange, red and black with increasing titanium content.

These volcanic glass beads have been found to contain surface correlated volatiles such as Cu, Zn, Pb, S, and Cl. More recently, they have also been shown to contain tens of ppm of indigenous H_2O. Even higher H_2O concentrations of >1000 ppm have since been found in olivine-hosted melt inclusions from the same deposit, bringing lunar pyroclastic deposits to the forefront for lunar volatile studies.

Despite the importance of pyroclastic deposits, their thermal and degassing histories remain poorly understood. Here, we combine H_2O, F, Cl, and S concentration data on olivine-hosted melt inclusions, melt embayments, and volcanic glass beads from Apollo sample 74220 to show that their degassing records are consistent with these eruption products remaining hot on the lunar surface for a prolonged period following the eruption.

This slow cooling process is further supported by one-dimensional thermal modeling. During slow cooling, the pyroclastic deposits may continue to degas and supply volatiles, sustaining a temporary local atmosphere. Prolonged cooling and slow degassing of pyroclastic deposits also provide a mechanism for redistribution of volatiles among glass beads buried at different depths, potentially explaining the enrichment of surface-correlated volatiles, volatile ingassing, and light-isotope enrichment in zinc and copper as previously reported.