Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.37074

Sulfur in lunar apatite reveals localized volatile processes relevant to metal mobility

DR. GIULIA CONSUMA[1], SAMANTHA FAIRCLOTH[2], XUCHAO ZHAO[2], FRANCESCA E. MCDONALD[1], JAMES CARPENTER[1] AND MAHESH ANAND[2]

[1]European Space Agency, European Space Research and Technology Centre (ESA/ESTEC)
[2]The Open University

Understanding the mobility of sulfur in the lunar interior is fundamental for reconstructing volatile behaviour, redox evolution, and potential redistribution of metals during magmatic differentiation. The lunar mantle is generally considered isotopically homogeneous in sulfur, an assumption based on the limited $\delta^{34}S$ variability observed in mare basalts and troilite grains.

To investigate whether small-scale processes relevant to metal mobilization may be detectable in lunar samples, we conducted simultaneous NanoSIMS analyses of S and Cl isotopes in apatite, complemented by S isotope analyses of troilite, across a broad range of lunar lithologies from multiple Apollo landing sites. Apatite displays a far wider range of S and Cl abundances and isotopic compositions than coexisting sulfides, with some differences by landing sites. While many grains preserve mantle-like $\delta^{34}S$, others exhibit pronounced deviations toward both heavier and lighter signatures, indicating localized fractionation occurring at small spatial scales during late-stage melt evolution. Some samples show significant S-Cl correlation consistent with closed-system concentration of incompatible elements during crystallization. In contrast, large S isotope excursions decoupled from Cl point to open-system behaviour, including oxidizing micro-environments, vapor–melt interaction, and magmatic degassing.

These isotopic fractionations suggest changes in S and Cl speciation that regulate ligand availability and metal-ligand complex formation, processes that strongly control metal solubility and mobility in magmatic systems. Our data therefore reveal the chemical conditions that would enable metal mobility where metals are present. In addition, apatite grains from different textural settings (apatite enclosed in pyroxene *vs.* apatite within mesostasis domains) show comparable isotopic variability, indicating that these signatures reflect magmatic conditions at apatite crystallization rather than post-magmatic processes. These microscale records provide new constraints on volatile-driven redox and speciation dynamics in lunar magmas and highlight the processes that could, under appropriate conditions, concentrate or redistribute metals, refining models of potential resource formation in localized lunar environments.