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Spinel-rich lithologies in the lunar highland crust: Linking lunar samples with crystallization experiments and remote sensing†

Juliane Gross[1,3,*], Peter J. Isaacson[2], Allan H. Treiman[3], Loan Le[4] and Julia K. Gorman[3,‡]

[1]Department of Earth and Planetary Sciences, American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024, U.S.A.
[2]Hawaii Institute of Geophysics and Planetology, School of Ocean and Earth Science and Technology (SOEST), 1680 East-West Road, Post 508B, Honolulu, Hawaii 96822, U.S.A.
[3]Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston, Texas 77058, U.S.A.
[4]Jacobs Technology, JETS, NASA Johnson Space Center Engineering, Technology and Science, 2101 NASA Parkway, Code KR111, Houston, Texas 77058, U.S.A.

Abstract

Mg-Al spinel is rare in lunar rocks (Apollo and meteorite collections), and occurs mostly in troctolites and troctolitic cataclastites. Recently, a new lunar lithology, rich in spinel and plagioclase, and lacking abundant olivine and pyroxene, was recognized in visible to near-infrared (VNIR) reflectance spectra by the Moon Mineralogy Mapper (M^3) instrument on the Chandrayaan-1 spacecraft at the Moscoviense basin. These outcrop-scale areas are inferred to contain 20–30% Mg-Al spinel. Possible explanations for the petrogenesis of spinel-bearing and spinel-rich lithology(s) range from low-pressure near-surface crystallization to a deep-seated origin in the lower lunar crust or upper mantle. Here, we describe 1-bar crystallization experiments conducted on rock compositions rich in olivine and plagioclase that crystallize spinel. This would be equivalent to impact-melting, which is moderately common among lunar plutonic rocks and granulites. To explore possible precursor materials and the maximum amount of spinel that could be crystallized, a lunar troctolitic composition similar to Apollo pink spinel troctolite 65785, and a composition similar to ALHA81005 as analog to the source region of this meteorite have been chosen. The crystallization experiments on the composition of AHLA 81005 did not yield any spinel; experiments on the composition similar to Apollo 65785 crystallized a maximum of ~8 wt% spinel, much less than the suggested 20–30% spinel of the new lithology detected by M^3. However, our VNIR spectral reflectance analyses of the experimental run products indicate that the spinel composition of the experimental run products not only appears to be similar to the composition of the spinel lithology detected by M^3 (characteristics of the spinel absorption), but also that the modal abundances of coexisting phases (e.g., mafic glass) influence the spectral reflectance properties. Thus, the spinel-rich deposits detected by M^3 might not be as spinel-rich as previously thought and could contain as little as 4–5 wt% spinel. However, the effect of space weathering on spinel is unknown and could significantly weaken its 2 μm absorptions. If this occurs, weathered lunar rocks could contain more spinel than a comparison with our unweathered experimental charges would suggest.

Keywords: Lunar, pink spinel, M^3, V/NIR reflectance spectra, crystallization experiments, spinel-rich lithologies, remote sensing, Apollo 65875