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A possible origin of the lunar spinel-bearing lithologies as told by the meteorite NWA 13191

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Abstract

Pink spinel anorthosite (PSA) and pink spinel troctolite (PST) are two lunar lithologies known to contain Mg-rich spinel. PSA rich in spinel and lacking mafic minerals, was detected by the visible and near-infrared reflectance spectroscopy. PST clasts were found in returned lunar samples and meteorites. NWA 13191 is a recently approved lunar meteorite that contains a large amount of spinel-bearing clasts and provides an opportunity to discuss its origin. Sixty-four spinel-bearing clasts were studied in this research. These clasts are dominated by anorthitic feldspars (20.8–80.9 vol%, $An_{90.9–96.8}$), mafic-rich and aluminum-rich glass (14.7–72.1 vol%) quenched from a melt, and spinels (0.19–5.18 vol%). Forty-nine of these clasts appear to have unusually low modal abundances of mafic silicates (avg. olivine ± pyroxene, 1.87 vol%), which distinguishes them from known spinel-bearing lunar samples (e.g., PST). The spinel compositions (avg. Mg# = 90.6, Al# = 97.4) and mafic minerals contents are basically consistent with those of PSA. The absorption characteristics of glass in the reflection spectrum are not obvious, so it is not clear if the PSA contains melt. The simulated crystallization experiment clearly shows that it contains a large amount of melt at the spinel crystallization stage. These phenomena provide experimental and sample evidence for the existence of glass in the lunar spinel-bearing lithologies. NWA 13191 records the highest known bulk Mg# (avg. 89.8), and the spinel records the highest Al# (98.8) and Mg# (93.1) of lunar samples to date. The chemical properties of spinel-bearing clasts in NWA 13191 are consistent with the slightly REE-enriched and alkali-poor Mg-suite rocks, such as PST, magnesian anorthosites (MANs), and olivine-enriched Mg-suite rocks. These phenomena and previous simulated crystallization experiments indicate that a Mg-Al-rich melt may be produced by impact melting of Mg-rich anorthosite precursors. The spinel is a metastable crystallization product along with plagioclase and vitric melt near the Moon's surface. This realization provides observational evidence for previous simulated crystallization experiments and theoretical speculations.

Keywords: Lunar meteorite, spinel, Mg-rich anorthosites, origin, impact melting, PSA, PST