SPATIAL DISTRIBUTION OF SPINEL IN THE ORIENTALE BASIN: NEW INSIGHTS FROM M^3 DATA.

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Introduction: Spinel dominant rock exposures lacking mafic minerals, olivine and/or pyroxenes, have been reported from certain areas on the Moon using data from NASA's Moon Mineral Mapper (M^3) onboard Chandrayaan-1, India's first mission to the Moon. On the far-side of the Moon they have been reported along the ring of Moscoviense basin, where they were first discovered [1] and in the Lowell crater located in the NW section of Orientale basin [2]. The near-side exposures have been reported from Sinus Aestuum, Theophilus crater, Copernicus crater, Tycho crater and surrounding regions of crater Endymion [3-8]. The mode of formation of this newly discovered rock type on the Moon is not clearly understood in the current perspective about the evolution of Moon. Most of the above mentioned exposures have been reported from similar geologic settings i.e., along the margins of basins and mega-sized craters. Hence, it is envisaged that plausibly most of these rock exposures constitute previously deep-seated rocks which have been exhumed on to the surface due to impacts. Finding similar exposures at other locations on the Moon and mapping them is essential to test this hypothesis, to constrain the extent of these rocks in the lunar crust and to understand the petrographic conditions for its formation.

The Study: The proto-type multi-ring Orientale basin offers access to study its various components since unlike other basins on the Moon, it is only partially filled with basalts. Here, using M^3 data, we have carried out spectral reflectance study of the Orientale basin, especially of non-mare regions to decipher the geologic settings in which spinel dominant rocks occur and to find out the association of mineral assemblages in their adjacent rock units.

Data used: Global mode Level-2 M^3 hyperspectral data [9,10] provided through public access web portal http://ode.rsl.wustl.edu/moon have been used in the study. The dataset comprises of 28 M^3 strips each with 83 near-contiguous bands spanning 540 – 2980 nm. The spatial resolution is 140 meters and the spectral resolution varies between 20 – 40 nm depending upon spectral range. The data is photometrically and thermally corrected.

Methodology: For carrying out regional study, a mosaic of the Orientale basin has been prepared by georeferencing individual data strips using LOC file provided with the data and mosaicking them using ENVI image processing software. The spectral reflectance curves (SRC) have been derived from fresh craters and slopes where the effect of space weathering is minimal. Surface composition have been identified on the basis of characteristic spectral signatures of the dominant mineral present. Spinel dominant lithology with anorthosite and scarcity of mafic silicates such as olivines and pyroxenes are identified on the basis of a prominent broad absorption feature centred at ~2μ but with no/ very weak absorption feature at ~1μ [1]. In contrast, olivine shows a single composite absorption centred ~ 1.1 μ, the pyroxenes show two broad absorption features centred at ~1 μ and 2 μ, crystalline plagioclase exhibits a minor broad absorption band centered at ~ 1.25 μ and shocked plagioclase shows a featureless monotonically increasing spectra. High Ca pyroxenes are distinguished from low Ca-pyroxenes on the basis of absorption at slightly longer wavelengths i.e. between 0.95 – 1 μ and ~ 2.2 μ compared to 0.9 - 0.95 μ and ~ 2 μ for low Ca pyroxenes.

Results: Signatures of spinel dominant exposures with little or no mafics but with abundant plagioclase (inferred from spectral shape) have been found in each of the geologic units of the basin i.e. in the Hevelius formation, Montes Rook Formation, Cordillera Ring, Outer Rook Ring and Inner Rook Ring. However, the number of exposures and specific rock associations have been found to vary from one setting to the other. Here we provide an account of the observations from each of these units. Spinel dominant spectra (denoted by S-UNIT) and adjacent rock spectra (denoted by A-UNIT) for selected representative sites from these units (marked in fig.1a) are shown in figures 1b,c and 1d,e respectively.

Hevelius Formation (HF). Numerous spinel rich exposures have been identified, especially, on the walls and floor of some of the fresh craters (S-HF). The accompanying rocks in the adjacent areas are mostly rich in pyroxene (A-HF).

Montes Rook Formation (MRF). Prominent spinel dominant exposures have been observed in important geologic units of MRF such as Lowell crater [2] (S-MRF) and the source crater for the pyroclastic ring. The other units such as small fresh craters and surface irregularities also show spinel exposures. The accompanying rocks generally show pyroxene signatures with signs of prominent hi-Ca pyroxene at certain places such as in the central peak of Lowell crater (A-MRF).

*Cordillera Ring (CR).*This outermost ring of Orientale basin show few spinel rich zones (S-CR). The accompanying rock is generally shocked anorthsite (A-CR) with few exposures of pyroxenes in some areas.

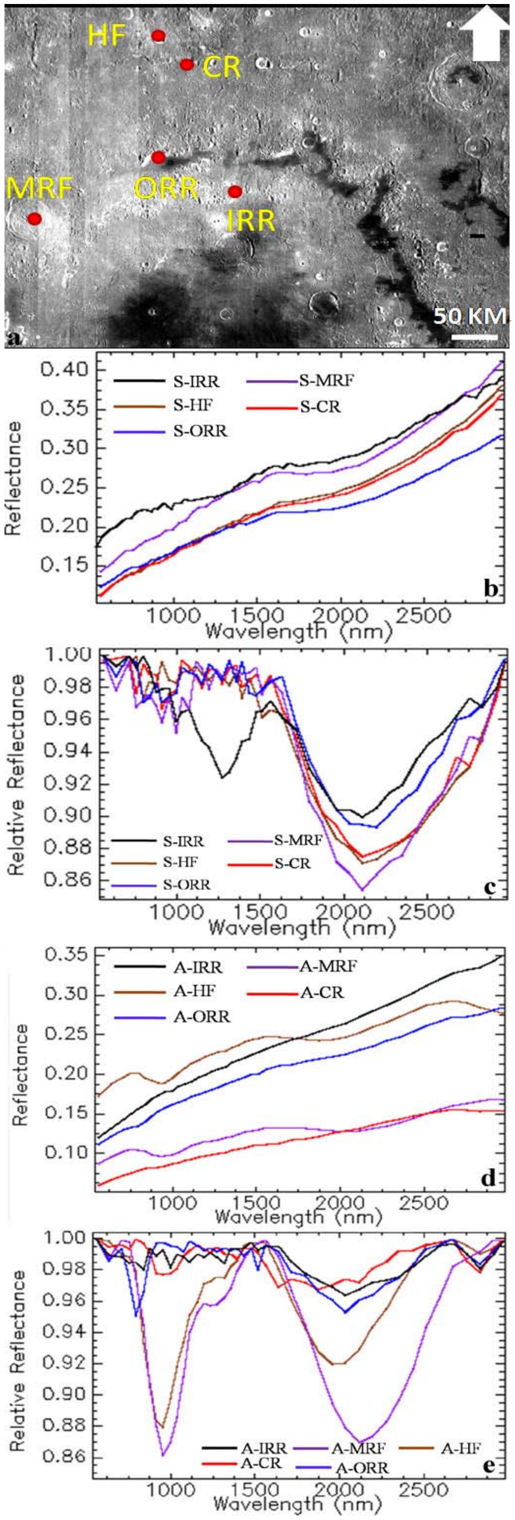

Figure 1: (a) A portion of the Orientale basin showing sites for which representative spectra have been plotted; (b,c) 4 pixel average SRC and continuum removed spectra for spinel dominant exposures. Rare co-existence of unshoked anorthosite and spinel in S-IRR is notable; (d,e) 4 pixel average SRC and continuum removed spectra from adjacent sites in the respective sites.

Outer Rook Ring (ORR). The ORR shows abundant discrete spinel dominant zones [S-ORR] with anorthosite [A-ORR] and pyroxene dominant rock types in the adjacent regions.

Inner Rook Ring (IRR). Contrary to the other regions of Orientale basin, interestingly, IRR, which is supposed to have sampled rocks from maximum depth is largely devoid of spinel. It shows signatures of abundant shocked and unshocked varieties of anorthosite (A-IRR) consistent with [11]. Very few spinel exposures have been observed which are also found to be associated with crystalline anorthosites (S-IRR).

Discussions and Conclusion: The spatial distribution of spinel dominant rocks and their associations observed in non-mare units of Orientale basin, particularly the spinel scarcity in IRR, indicates absence of deep-seated pervasively spinel rich layer in the primordial crust. Further, the co-existence of spinel +anorthosite exposures and pyroxenes in adjoining areas at several locations in HF, MRF and ORR strongly suggests that spinel was present alongside pyroxene and anorthosite at a comparatively lesser depth and were excavated during the Orientale forming impact. This scenario could be possible in case the spinels were produced apriori, due to melt - wall rock reaction [12] during ancient pre-Orientale magmatism. If so, the abundance of spinel dominant exposures observed here indicate that the ancient magmatism would have been quite intense in the Orientale region.

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