NIR SPECTRAL CHARACTERIZATION OF THE NORTHERN IMBRIUM REGION FROM SIR-2 DATA.
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Introduction: The near infrared (NIR) reflectance spectrometer SIR-2 read the solar photon numbers off the lunar surface which absorption features vary according to mineralogy, physical state of the constituents, illumination conditions, morphology, and other key properties and characteristics of the exposed materials, averaged across an area of around 39,000 m^2. Almost the entire surveyed lunar surface is represented by a ubiquitous layer of dust-like materials (regolith) that mantles progressively curser layers of shattered and reworded rocks. We have developed a classification method of spectral characterization that appears to differentiate reliably between known heterogeneous surface materials; this offers, in its full library of 33 bin groups (fig. 1), the opportunity of mapping petrological units across the whole Moon with unprecedented confidence. Here we present an introduction and preliminary report, focused on six of the most recurrent spectral shapes.

The investigated area: The geology of the Imbrium Basin has been the target of intense scientific investigation through the ages [1]. Further, since its eastern outer reaches were sampled directly by the Apollo 15 mission, the composition of the surface materials have been subjected to thorough laboratory investigations and employed as ground truths for later remote sensing studies [e.g. 2]. The northern section of the Imbrium basin is of a particular geological interest due its suspected unusual noritic composition [e.g. 3], spectral anomalies (Lunar Red Spots, e.g. crater Plato's rim [4], and maria of different geological ages [e.g. 5,6,7].

The instrument and data set. The MPS designed SIR-2 instrument, which formed part of the scientific payload of the Chandrayaan-1 Indian lunar polar orbiter mission [8], collected high spatial resolution (~200 m) near infrared data of the area under investigation (~33,000 sample points in total) during 39 separate flyovers (orbits 1072 to 1110) using a Grating NIR Point Spectrometer, at wavelengths between 0.9 and 2.4 microns with a spectral resolution of 6 nanometres.

Method of analysis: The Comparative Normalization Analysis (CNA) method we introduced in our 2011 paper [9] does not attempt a full deconvolution of the diagnostic spectral types, let alone a mineralogical modal survey of each spectrum. However, it takes advantage of the two main strengths of the SIR-2 instrument: its high spectral resolution and crucially, the uniformity and consistency between spectral samples during its 100 km altitude mission phase. Our CNA technique, through a process of double normalization, scaling, and targeting of selected diagnostic wavecenters (see fig. 1B), allows for the classification and grouping of spectral shapes whilst minimizing soil maturity and shadowing factors. The process relies on a custom database of over 100 spectral shapes (fig. 2, right insets) based on laboratory data sourced from both theoretical and actual mineralogical samples. We found that our spectral shapes match on average around 98% of the readings, with the few unknowns probably corresponding to shadowed/dark areas, very mature soils, or rare spectral signatures. In time, we aim to build a more comprehensive database to encompass these unclassified spectra.

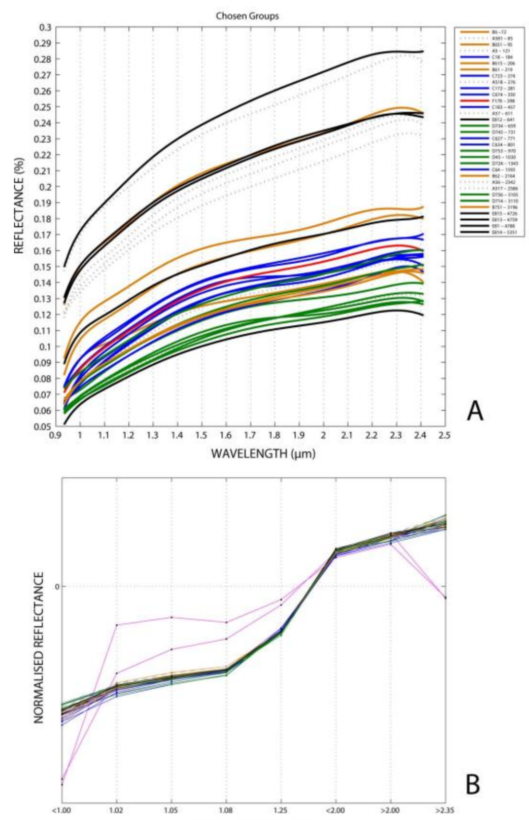

Figure 1. 'A': chosen representative samples' spectra. 'B': same data following normalization and wavecenters selection.

Discussion: The six most recurrent spectral types cover around ~90% of the area under investigation (fig. 2). Broadly, these groups cover three distinct geological settings: '*a*', uplands, including "montes"; '*b*' Imbrian-age mare; and ‘*c*’ Eratosthenian flows. This is by no means a clear-cut classification and much detail and complexity is apparent even at this level of over simplification. ‘*a*1’ for instance, which absorption features point to the presence of orthopyroxene, is strongly represented on all elevated terrains but also across the western basalts of Sinus Iridum and Plato. We interpret these spectra as belonging to materials with an anomalously noritic composition (NIN, [3]). ‘*a*2’ type is present along the ‘mare shores’ and absent in the north towards Mare Frigoris. Interestingly, these materials are also represented in ‘younger’ mare flows, such as the eastern half of Plato, the Eratosthenian flow northeast of Montes Recti, and south of Promontorium Laplace.

Type ‘*b*1’ is associated with the exposed Imbrian mare flow units [7], but with a conspicuous gap in the southeastern half of Mare Imbrium which is mantled by ejecta from the Aristillus impact. Samples of materials with similar spectral signatures are found around craters that have excavated these early lava infills, such as Helicon and Le Verrier. ‘*b*2’ spectra are present in comparable geological settings as ‘*b*1’ but with a stronger presence in Mare Frigoris and across Sinus Iridum. The 2 µm absorption feature is also shifted redwards in comparison to ‘*b*1’ suggesting a more ‘gabbroic’ mineralogical imprint (i.e. higher Ca-rich pyroxene fraction and olivine).

Type ‘*c*’ corresponds with the dominant spectral phase in the Eratosthenian lava flows, in particular ‘*c*2’. Also to note its widespread occurrence across eastern Plato and the distal ejecta related to crater Aristillus.

Conclusions: Our preliminary results hints at the tantalizing prospect of a moon-wide classification of distinct NIR spectral signatures corresponding to known and yet to be constrained petrological types. Further, high-quality NIR data yields the potential of offering a new key in unscrambling and mapping the complex geology and distribution of exposed lunar materials.

References:

[1] Gilbert, G.K. (1893) *Washington, The Society, 1893.* [2] Rhodes and Hubbard (1973) *LPSC Proceedings IV*, 1127. [3] Isaacson, P.J. and Pieters C.M. (2009) *JGR* 114, E09007. [4] Wood, C.A. and Head, J.W. (1975) *Origins of Mare Basalts* (LSI), 189. [5] Head (1976) *Rev. of Geophy. & Space Phys*., 14, 256-300. [6] Hiesinger et al. *JGR*, 105, 29239-29276. [7] Bugiolacchi and Guest (2008) *Icarus 197, 1-18.* [8] Mall U. et al. (2009) *Current Sci. 96, No 4.* [9] Bugiolacchi et al. (2011) *Icarus* 213, 43-63.

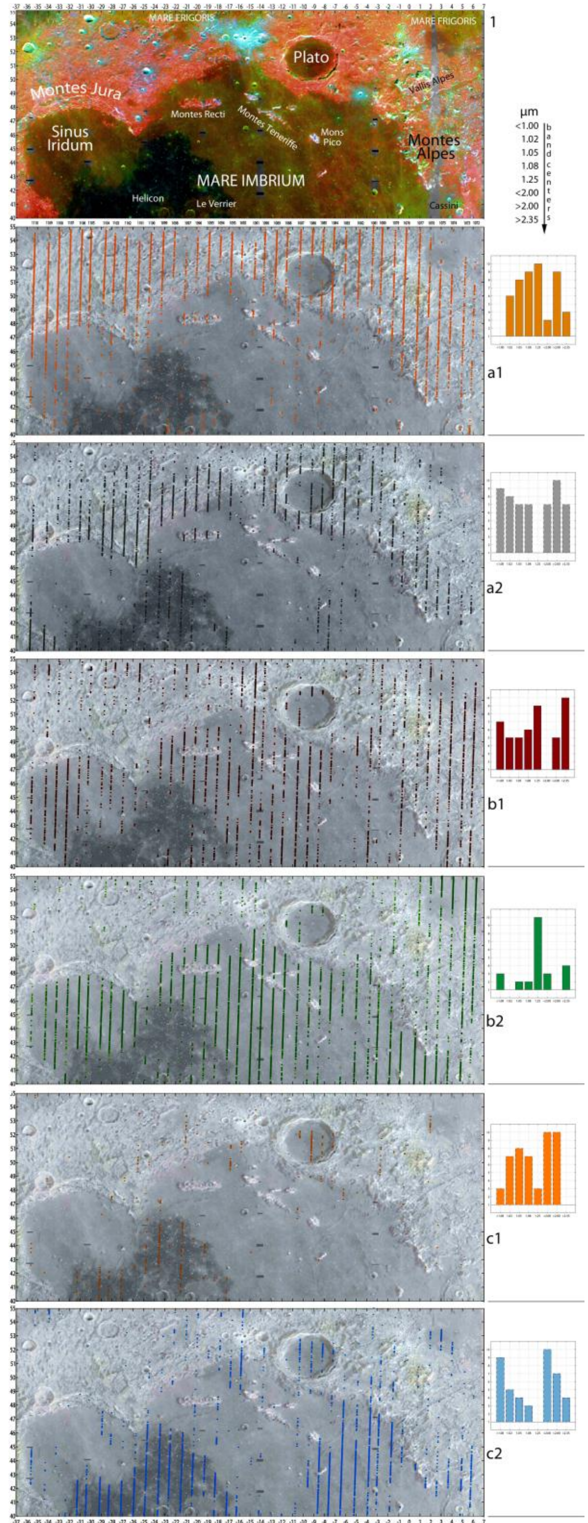

Figure 2. Northern Imbrium Region. Basemaps from Clementine data (Color Ratio and NIR filter). Lines represent similar sample spectral characteristics superimposed on corresponding SIR-2 orbit footprints (size exaggerated). Insets on the right show the eight absorption centers scaled from 1 to 10 (1=strongest wavecentre absorption).