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Mineralogy of the lunar crust from VNIR spectroscopy

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1. Lunar mineralogy through spectroscopy

The Moon is a critical solar system body for geologic investigation, as it harbors a preserved record of fundamental processes in early planetary formation and evolution. Lunar rocks contain a record of these processes in the relative abundance and composition of key minerals. In addition to mineral abundance and composition, the geologic context of lunar rocks provides important constraints on their origin and evolution. Returned samples and lunar meteorites offer the most direct and concrete insight into lunar geology. However, this collection of samples is geographically limited or unconstrained, and recent results have demonstrated that materials not found in the sample collection are present on the lunar surface or near-surface [3, 9]. Remote sensing offers the capability for global investigations of lunar geology, and visible to near-infrared (VNIR) spectroscopy has the unique capability of evaluating mineral abundance and composition at high spatial resolution due to the presence of diagnostic mineral absorption features across this wavelength range [e.g., 2]. We are conducting a systematic survey of the mineralogy of the lunar crust using orbital VNIR spectroscopy that will provide extraordinary new insight into the geology of the Moon.

2. Lunar sample context

Interpretation of remotely-acquired VNIR reflectance spectroscopy data is fundamentally tied to laboratory investigations of samples and analogue materials. Synthetic mixtures of endmember minerals do not capture important subtleties found in real lunar samples, which can have profound implications for interpretation of the spectra. Additionally, terrestrial minerals differ in important ways from their lunar analogues. For these principal reasons, measurement of lunar samples is essential for remote exploration of lunar mineralogy, especially given that the Moon is the only solar system body other than the Earth from which we have samples from known locations to validate spectral reflectance measurements. Examination of lunar samples with laboratory spectroscopy has also led to major breakthroughs in our understanding of the space weathering process that has shaped the vast majority of the lunar surface [e.g., 7]. Example laboratory reflectance spectra of lunar samples, which are used as ground truth for and interpretation of remotely-acquired VNIR reflectance spectra, are shown in Figure 1.

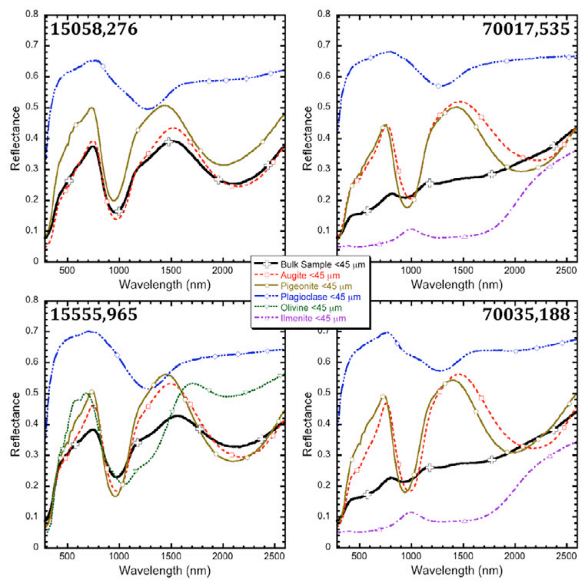

Figure 1: Laboratory VNIR reflectance spectra from [5] of lunar samples used for ground truth and interpretation of remote reflectance spectra. Black lines are basalts; colored lines are mineral separates from the basalts. Low-Ti samples are on the left and ilmenite-rich high-Ti samples are on the right. Note the dramatic effect of ilmenite on reflectance spectra illustrated by the differences between the low-Ti and high-Ti basalt spectra.

3. Mineral composition

Mineral composition is in important clue to the formation processes or a particular lithology. For example, Mg-rich olivines tend to be quite primitive (early-formed, with little previous processing of the source region), whereas more Fe-rich olivines tend to indicate more evolved lithologies [e.g., 1]. VNIR reflectance spectra of lunar minerals can be used to determine their composition [2]. An example is shown in Figure 2, which illustrates laboratory reflectance spectra of synthetic olivine samples over a range of compositions [4]. However, such determinations require high-quality spectral reflectance measurements, including high spectral resolution and high signal-to-noise ratios.

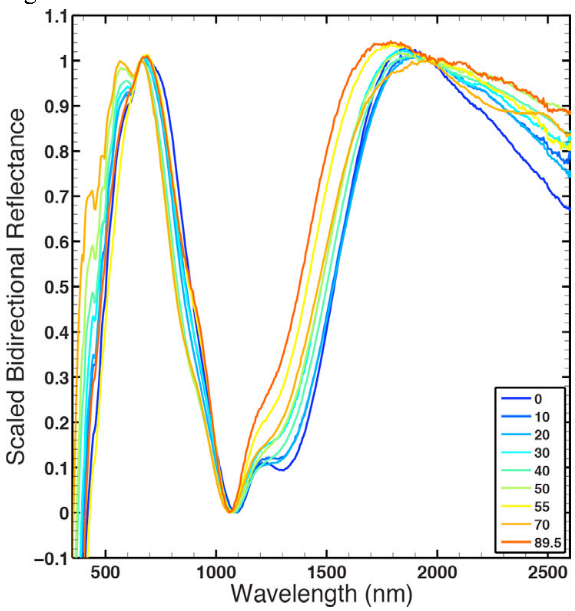

Figure 2: Reflectance spectra of synthetic olivine samples. Spectra have been normalized to their maximum band depth and are labeled with their Fo content (Mg'). The olivine absorption near 1 μm is composed of three overlapping absorptions that change with mineral composition.

4. Compositional structure of the lunar crust through M³ imaging spectroscopy

The NASA Moon Mineralogy Mapper (M^3) is a VNIR imaging spectrometer that orbited the Moon on the ISRO Chandrayaan-1 spacecraft. It covers the wavelength range from ~650 to ~3000 nm at high spatial and spectral resolution, and acquires reflectance spectroscopy data in an imaging context, providing the critical third dimension of spatial/geologic context [8]. The spectral sampling of M^3 ranges from 20–40 nm in the instrument's reduced resolution mode (which comprises the bulk of the acquired data), allowing analyses that require high spectral resolution and full coverage across VNIR wavelengths. This capability represents a substantial advancement over previous analyses based on multispectral imaging, which could not capture the subtle spectral variations critical for full mineralogical analyses.

M^3 reflectance spectroscopy data enable simultaneous investigation of mineralogy (relative abundance of key minerals), mineral composition, and geologic context. Example analyses of mineral compositions with M^3 VNIR spectroscopy data are illustrated in Figure 3, which shows relative compositional evaluations of lunar olivines from [6]. Our survey of the lunar crust is providing these constraints at a global scale. These constraints will greatly enhance our knowledge of the compositional structure of the lunar crust, which is a fundamental clue to our understanding of the geologic evolution of the Moon.

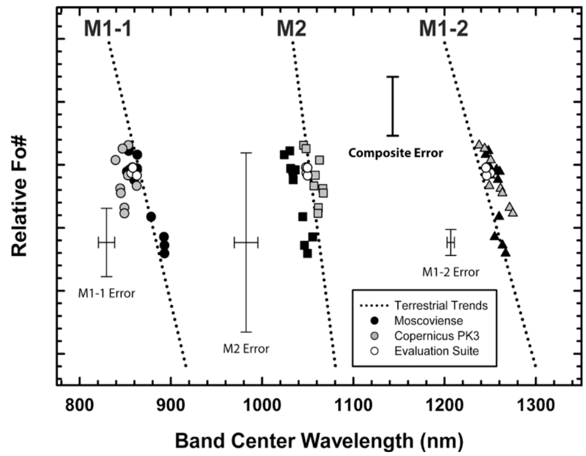

Figure 3: Compositional evaluation of lunar olivine-rich lithologies from [6]. The olivine band positions used to evaluate composition are shown on the x axis, and the relative composition (in Fo# units) is shown on the y axis, with higher numbers indicating relatively Mg-rich compositions. The results are compared to a Mg-rich terrestrial standard (white circles).

References

[1] BVSP (1981) Basaltic Volcanism on the Terrestrial Planets.

[2] Burns, R. G. (1993) Mineralogical applications of crystal field theory.

[3] Dhingra, D., et al. (2011) Geophys. Res. Lett., 38, L11201, 10.1029/2011gl047314.

[4] Dyar, M. D., et al. (2009) AM, 94, 883-898, 10.2138/am.2009.3115.

[5] Isaacson, P. J., et al. (2011) MAPS, 46, 228-251, 10.1111/j.1945-5100.2010.01148.x.

[6] Isaacson, P. J., et al. (2011) JGR, 116, 10.1029/2010JE003731.

[7] Pieters, C. M., et al. (2000) MAPS, 35, 1101-1107, 10.1111/j.1945-5100.2000.tb01496.x.

[8] Pieters, C. M., et al. (2009) Current Science, 96, 500-505.

[9] Pieters, C. M., et al. (2011) JGR, 116, 10.1029/2010JE003727.