PROGRESS TOWARD A NEW LUNAR OPTICAL MATURITY MEASURE BASED ON MOON MINERALOGY MAPPER (M^3) DATA.

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Introduction: Lunar surface materials are modified over time by exposure to solar wind and micrometeorite bombardment ("space weathering"). The effects of this process on the optical properties of surface materials is one of the primary hinderances of the interpretation of lunar spectra. For this reason, several approaches for estimating degree of space weathering have been attempted [1, and references therein]. These methods have largely been successful to first order, but have been hindered by the available data's ability to capture space weathering effects. The Moon Mineralogy Mapper [M^3, 2] provides a new dataset with a much higher spectral resolution and coverage than that of previous lunar orbiting spectrometers, and thus represents an opportunity to quantify and map the effects of space weathering on lunar spectra in more detail than had been possible previously.

Previous Work: The common optical maturity index in the literature is the OMAT parameter, developed for Clementine UV/VIS data [1]. Briefly, the OMAT parameter is defined as the distance between a datapoint of interest and a hypothetical, hypermature endmember on a plot of albedo (reflectance @ 0.75 µm) versus the $R_{0.95}/R_{0.75}$ ratio, where $R_{0.95}$ and $R_{0.75}$ are the reflectances at 0.95 and 0.75 µm, respectively.

Space weathering affects near infrared spectra in three ways: a lowering of albedo, weakening of absorption band depths, and, in many cases, by reddening of the spectral continuum. By plotting albedo vs. $R_{0.95}/R_{0.75}$, an estimate of two of these effects, weakening of band strengths and lowering of albedo, is achieved.

The OMAT parameter has been shown to correlate with several other indices of space weathering, most notably I_s/FeO [1]. However, since it was developed for 5-band Clementine UV/VIS data, it is based on only two spectral bands. Also, these two bands are in the UV/VIS, which means optical effects of space weathering that occur outside of this spectral region are not captured by OMAT.

Since its introduction, the OMAT parameter has been revised in attempts to better capture the spectral effects of space weathering. [3] calculated a new, better optimized hypermature endmember origin for OMAT derived directly from Clementine data, making it much more applicable to that dataset since the original origin was developed from hemispherical laboratory spectra. [4] used a measure of the continuum slope and a band depth estimation at longer wavelengths to estimate maturity. We present here initial efforts to leverage M^3's much higher spectral resolution and coverage to further refine optical maturity estimates.

Dataset and Methods: M^3 is a pushbroom imaging spectrometer that acquires data in the 0.43-3.0µm wavelength range. The spectrometer operates in two modes: a higher resolution mode with 260 spectral bands and 70m/pixel spatial resolution, and a lower resolution mode with 85 spectral bands and a 140m/pixel spatial resolution. The data presented were acquired in the lower resolution mode. M^3 data are calibrated to radiance using prelaunch and inflight calibration coefficients and then converted to apparent reflectance by dividing by the solar spectrum and the cosine of the incidence angle. A correction factor was applied to suppress residual band-to-band artifacts in the spectra. No thermal correction has been applied to the data presented here.

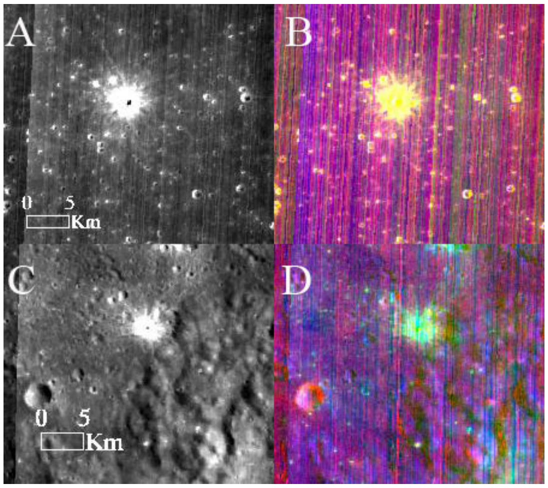

Figure 1. Study areas: A) Apparent reflectance image @0.75µm of a small fresh crater in Mare Serenetatis. B) Color composite of A: R=integrated 1µm band depth (IBD1000), G=continuum offset, B=continuum slope. C) 0.75µm apparent reflectance image for South Ray Crater near the Apollo 16 landing site. D) Color composite for C, same RGB combination as in B. Continuum slope and offset calculated as in [5]. North is to the top in each image.

The goal of our work is to develop a new optical maturity estimate that leverages the high spectral resolution and spectral range of the M^3 data. To date, we have focused primarily on attempts to refine estimates of the three effects of space weathering individually, with the ultimage goal of combining them into a single estimate of maturity.

To show the weakening of band depth with maturity we calculate a 1 µm band depth parameter using R_{1050} and R_{750}. We calculate a continuum slope two ways: one in the method of [5], which also gives us a continuum offset and was used in Figure 1. The second continuum slope calculation was actually a simple ratio of R_{1580}/R_{670}. This second continuum slope formulation should be insensitive to albedo and is used in Figure 2. Albedo is represented by apparent reflectance at 0.75 µm. These parameters use the 1µm band only, as the 2µm band's size and shape is distorted by thermal effects longward of ~2.2µm. Spectra with a model thermal removal, as well as any potential refinements to spectral parameters, will be used in future analyses.

We chose to focus on two small, fresh craters for this initial study (Figure 1). One crater is in Mare Serenatitis, whichwe chose as a representative mare location, and the other is South Ray Crater near the Apollo 16 landing site.

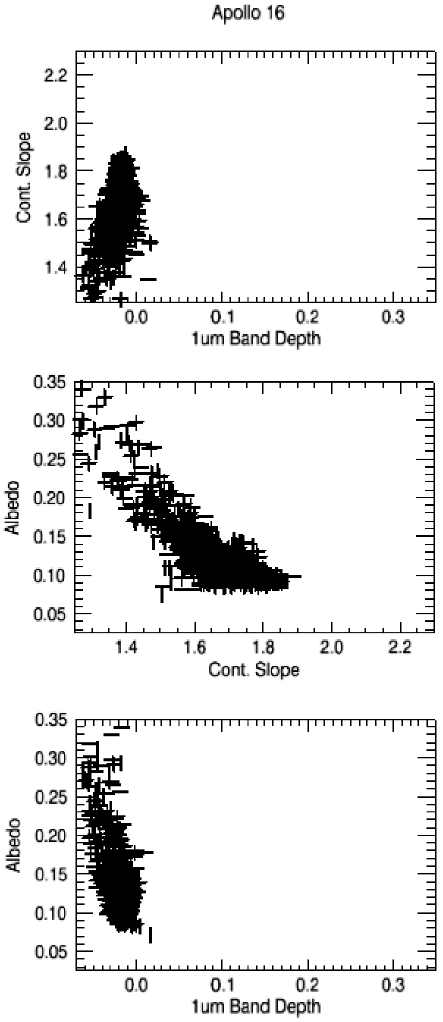

Figure 2. Spectral parameter calculations for the crater shown in Fig. 1 C & D.

Preliminary Results: Figure 2 illustrates the relationship between the three spectral parameters we used to describe maturity effects for the highlands study area. The relationship between continuum slope and albedo is as expected: higher albedos have the lowest slopes. Band depths in this area are neglible, and in fact go slightly negative in most cases, so they do not appear to follow expected trends. However, we believe this to be an artifact of calibration and is currently being investigated. At any rate, since the band depths are at most very small it is not surprising that they do not follow expected trends.

For the mare study area, however, all of the expected trends are evident in the results (Figure 3). Band depths are negatively correlated with continuum slope and proportional to albedo. This illustrates the likely need to consider mare and highlands separately in maturity calculations.

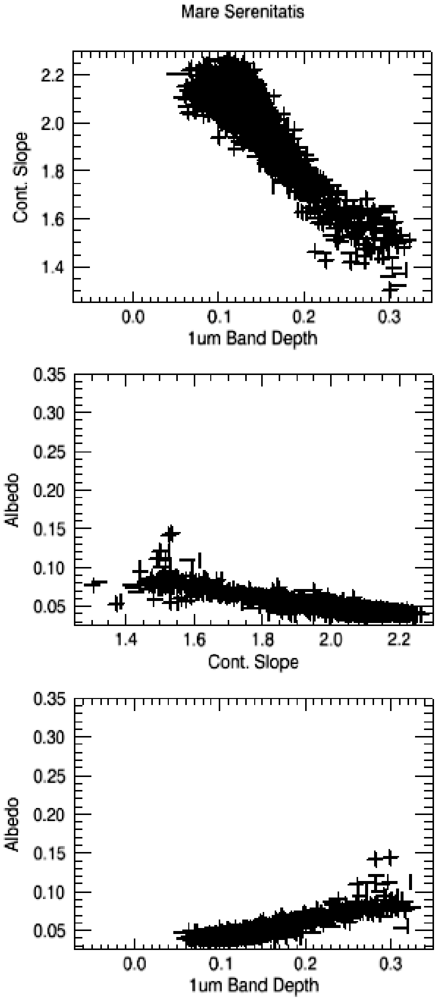

Figure 3. Spectral parameter calculations for the crater shown in Fig. 1 A & B.

Ongoing Work: We are currently working to combine the trends we observe in the M^3 data into a single maturity calculaton, or into a pair of algorithms (for highlands and mare areas). We are studying additional craters in both highland and mare areas to ensure that our results are representative. We are also refining our ability to determine each of the three space weathering effects on spectra by adjusting our parameter calculations.

References: [1] Lucey P. G. et al. (2000), *JGR, 105*, 20,377-20,386. [2], Green R. O. et al. (2009) LPSC 40, Abstract # 2307. [3] Lucey P. G. et al. (2000), *JGR, 105*, 20,397-20,305. [4] Le Mouelic S. M. et al. (2002), *JGR, 107*,doi:10.1029/2000JE001484. [5] Hiroi T et al. (1997) LPSC 28, Abstract #1152.