MOON MINERALOGY MAPPER VIEWS OF THE SCULPTURED HILLS: IMPLICATIONS FOR THE ORIGINS OF THE STATION 8 BOULDER FROM APOLLO 17.

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Introduction: The Moon Mineralogy Mapper (M^3) was a high spatial and spectral resolution imaging spectrometer that flew on the Chandryaan-1 Mission to the Moon [1-3]. Results from M^3 have shown the value of imaging spectroscopy at the Moon, enabling an improved assessment of the mineralogy of the Moon [3, 4]. One of many strengths of M^3 was the detailed detection of the variations in pyroxene composition [5] and in the distribution of olivines [6, 7]. While M^3 has shown that the Moon is rich with diversity across the entire lunar surface, it also provides the opportunity to revisit the Apollo landing sites and examine the diversity of materials in and around those sample sites. Of particular interest is the composition of materials in the massifs of the Tarus-Littrow Valley and how they may be reflected in the samples from Apollo 17. Recent data from the LRO Camera raises the question of the origin of the Sculptured Hills and suggests that they may be derived from the Imbrium Basin [8]. The Sculptured Hills were identified as being spectrally distinct in Clementine data [9, 10]. Here we revisit the diversity of materials in the Sculptured Hills and their possible connection to the Apollo 17's Station 8 boulder [11].

Apollo 17-Station 8: Station 8 is located about 20 meters above the Tarus-Littrow valley floor at the western base of the Sculptured Hills (Figure 1). At the site Astronauts Cernan and Schmitt collected rake samples from the rim of a small crater, took trench samples, and sampled portions of a small (~0.5 meter) boulder.

Station 8 Boulder (78235-78255): The boulder was selected for sampling as it was easily accessible. There are no boulder tracks leading to an outcrop of origin, suggesting that the boulder was delivered to the site ballistically [11, 12]. Samples of the boulder (Figure 2) are noritic with crystallization ages range from 4.11 to 4.426 Ga [12]. Samples of the boulder (78235) indicate that the modal mineralogy consists of 32-53.6% orthopyroxene and 68-39.2% plagioclase [13]. In terms of its rare earth contents samples of the boulder range in Th abundances from 0.44-0.83 ppm [11].

Jackson et al. [14] describe a possible history of the boulder including relevant events leading to its delivery to what would be Station 8. These are "At rest at an unknown location for about 0.75 m.y. with its bottom up, receiving micrometeorite craters on its glass coating. Movement to its discovery site at Station 8, where it rested, with top side up, for an amount of time approximately equal to that at its former site [14]."

Soil Samples: Additionally, soil sample 78220 was collected from beneath the boulder after it had been rolled over. The soils sampled from beneath the boulder are similar to soils collected elsewhere at Station 8 and was found to be very mature and contains a mixture of highlands material and mare fragments from the valley floor [11, 12]. A mixing model by Korotev and Kremser [15] suggested that the soils were composed of 28% mare basalt, 12% orange glass, 15.7% norite breccia, 35.7% anorthosite, and 7.7% of a high-Mg' component (only seen at stations along the North Massif).

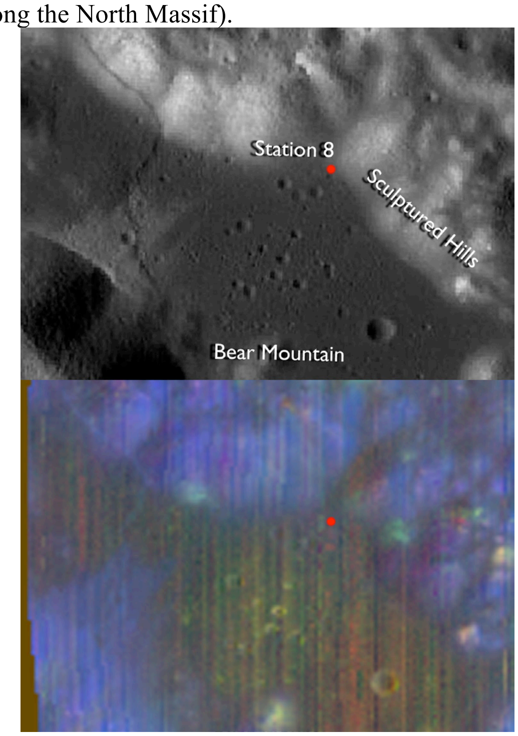

Figure 1. [Top] LRO WAC mosaic of the Taurus-Littrow Valley showing the location of Station 8, the Sculptured Hills, and Bear Mountain. **(B)** M^3 parameter map of the same region, where Red=1 μm integrated band depth; Green=2 μm integrated band depth, and Blue=1.5 μm reflectance [M^3 Image ID m3g20090203t080104]. Image width is 22 km.

M^3 Perspectives on Sculptured Hills Mafic Mineralogies: The sculptured hills and surrounding regions host a variety of mafic mineralogies, as illustrated in Figure 1. The band parameters depicted have been designed to highlight mafic mineralogy, in particular the relative strengths of the 1 and 2 μm absorption bands. In this composite, olivine-rich materials are redder, while orthopyroxene-rich materials tend to appear cyan. Typical lunar basalts and clinopyroxene-rich deposits appear yellow or orange, and anorthosite-rich regions appear blue. Within the sculptured hills themselves, an assortment of lithologies are present, ranging from noritic through gabbroic and potentially olivine-enriched massifs. The Bear Mountain Massif, located south of the Apollo 17 site, appears to be gabbroic.

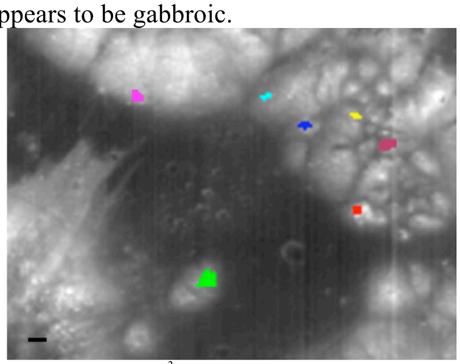

Figure 2. 750 nm M^3 image (m3g20090203t080104) with compositional regions of interest overlain. Scale bar is 1000 m.

To investigate the spectra further, we have defined several regions of interest, as illustrated in Figure 2. These include each of the largest mafic anomalies surrounding to the Taurus-Littrow Valley. Continuum-removed spectra for each of the regions of interest are presented in Figure 3. The freshest of the spectra, with the strongest absorption bands and brightest albedo, is the fresh landslide (red region of interest). Despite its slightly pink hue in the color composite, the spectrum does not suggest a large component of olivine in the rock. The yellow region of interest, further North, however, does exhibit a broadened absorption near 1 μm, suggesting some olivine may be present. The three sites closest to Station 8 have short wavelength 1 and 2 μm bands, consistent with being dominated by orthopyroxene. Both the Bear Mountain spectrum and the furthest eastern region of interest (maroon) exhibit longer wavelength pyroxene bands, consistent with a higher abundance of clinopyroxene. Unlike the basalts in the region, these spectra are significantly higher in reflectance, suggesting that they may be gabbroic rather than basaltic in nature.

Each of the orthopyroxene-enhanced locations near Station 8 exhibit spectra with similar band positions. However, only the furthest western spectrum (magenta) is suitable for compositional analysis using the Modified Gaussian Model (MGM). The MGM is designed to isolate the individual mafic bands in a spectrum by simultaneously fitting a continuum and all band parameters, allowing a quantitative analysis of the minerals in the rock [16]. Using the MGM, we estimate that the orthopyroxenes have an Mg number of 77-80 in the furthest western (magenta) region.

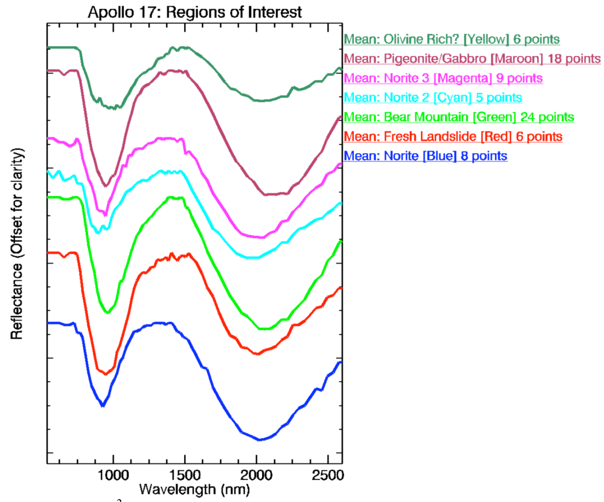

Figure 3. M^3 spectra for the regions of interest identified in Figure 2. Colors of the spectra correspond to the colors of the regions of interest on Figure 2, except for the yellow, which is shown as a dark green spectrum (the top spectrum).

Summary: The boulder at Station 8 represents one of the best examples of the Mg suite of norites sampled by Apollo [11, 17]. However, its lack of boulder trail and likely emplacement as an ejecta block confounds its origin and therefore ascribing a context to its source is difficult. However, the compositional information derived from M^3 suggest that the Sculptured Hills as a possible source. Based on the M^3 spectra there are a number of mafic anomalies in the Sculptured Hills, North Massif, and Bear Mountain. The mafic anomaly in the North Massif (magenta in Figures 2, 3) has the best spectra from which to derive compositions. The rock at that location is likely to contain 30-50% orthopyroxene and 4-7 weight % in bulk. These values are similar to the norites in the Station 8 boulder (78235).

Should any of the mafic units within the Sculptured Hills be compositionally similar and posses a large enough source crater they could represent potential source regions for the boulder. Given the possible origin of the Sculptured Hills [8], the formation of the boulder in the Imbrium Basin target region is possible.

References: [1] Boardman, J. W., et al., (2011) *JGR*, 116 [2] Green, R. O., et al., (2011) *JGR.*, 116, E00G19. [3] Pieters, C. M., et al., (2011) *JGR*, 116, [4] Dhingra, D., et al., (2011) *GRL*, 38, 11201. [5] Klima, R. L., et al., (2011) *JGR*, 116 [6] Isaacson, P. J., et al., (2011) *JGR*, 116 [7] Mustard, J. F., et al., (2011) *JGR*, 116, [8] Spudis, P. D., et al., (2011) *J. Geophys. Res.*, 116, E00H03. [9] Jolliff, B. L., (1999) *JGR*, 104, 14123-14148. [10] Robinson, M. S. and B. L. Jolliff, (2002) *Journal of Geophysical Research*, 107k, 20-21. [11] Wolfe, E. W., et al., (1981) *The Geologic investigation of the Taurus-Littrow valley, Apollo 17 landing site*. [12] Meyer, C., (1994) Lunar Sample Compendium [13] Edmunson, J., et al., (2009) *GCA*, 73, 514-527. [14] Jackson, E. D., et al., (1975) *GeoL Soc. Am. Bull.*, 86, 433-442. [15] Korotev, R. L. and D. T. Kremser, (1992), *PLPSC*,Abst. #275-301.[16] Sunshine, J. M. and C. M. Pieters, (1993) *JGR*, 98, 9075-9087. [17] James, O. B. and M. K. Flohr, (1983) *JGR*, 88, 603.