MOON MINERALOGY MAPPER PERSPECTIVE ON THE COMPOSITION OF THE SCULPTURED HILLS: IMPLICATIONS FOR THE ORIGIN OF THE APOLLO 17 STATION 8 BOULDER AND GUIDANCE FOR FUTURE LUNAR ROVERS. N. E. Petro[1] and R. L. Klima[2], [1]NASA Goddard Space Flight Center (Noah.E.Petro@nasa.gov), [2]Johns Hopkins University Applied Physics Laboratory.

M^3 Observations of the Sculptured Hills: 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 exploration sites. Of particular interest are the materials in the massifs of the Tarus-Littrow Valley, 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 boulder sampled at Station 8 of Apollo 17 [11].

Over the life of the Chandrayaan-1 mission, several observations of the Apollo 17 landing site were made by M^3. A handful of observations were made while the spacecraft was in its lower 100km orbit [1] resulting in a spatial resolution of ~140m/pixel (Figure 1). A strength of the M^3 dataset is the capability to create overviews of the mineralogical diversity of a region through the use of parameters [5, 6]. One such parameter set captures the strengths of the 1.0 µm and 2.0 µm ferrous absorption bands and the albedo around ~1.5 µm. Shown in Figure 2 is the Apollo 17 landing site with these three parameters displayed in the red, green and blue channels respectively. The diversity of materials in the Sculptured Hills is apparent, with plagioclase bearing rock appearing in blue/purple, pyroxenes appearing green and yellow, and olivine appearing red. Clementine data illustrated that the Sculptured Hills were diverse [10] but such data could not differentiate the specific mafic mineralogies. The Sculptured Hills show a greater diversity of materials than what is exposed in the North Massif (for example), generally supporting the hypothesis that they formed in a different manner possibly tied to the formation of the Imbrium Basin [8].

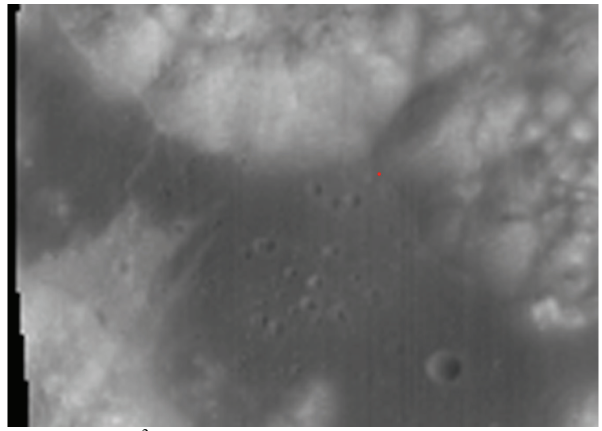

Figure 1. M^3 view of the Apollo 17 landing site at 750 nm (file ID m3g20090203t080104). The location of Station 8 is identified by a small red point.

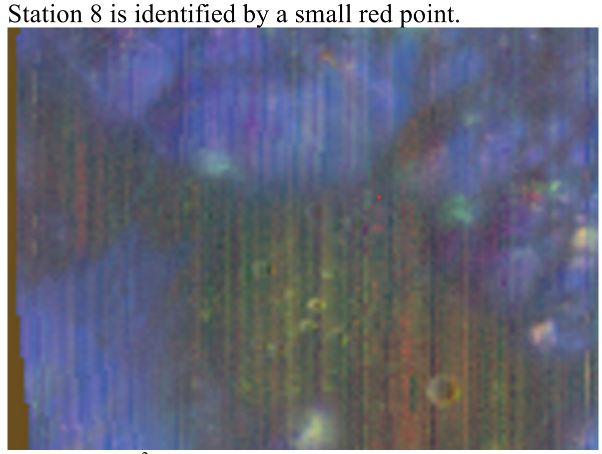

Figure 2. M^3 color composite of the Apollo 17 landing site illustrating the mineralogic diversity of the site. The Sculptured Hills, the eastern portion of the Taurus-Littrow valley, shows a previously unidentified diversity of materials. Small red dot identifies the location of Station 8 (file ID m3g20090203t080104).

Apollo 17 - Station 8 Boulder: Station 8 was located about 20 meters above the Tarus-Littrow valley at the western base of the Sculptured Hills. The boulder was selected as a sample target as it was easily accessible, yet contained no boulder tracks leading to an outcrop of origin [e.g., 12]. Samples of the boulder (Figure 3) are noritic in origin and range in ages from 4.11 to 4.426 Ga. Jackson et al. [13] 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 [13]."

Between the remote sensing data and sample composition, it is enticing to suggest that the Station 8 boulder is derived from one of the noritic (green in Figure 2) outcrops in the Sculptured Hills. Additional study of the composition of the Sculptured Hills and the Station 8 boulder samples will aid in determining what, if any, link exists.

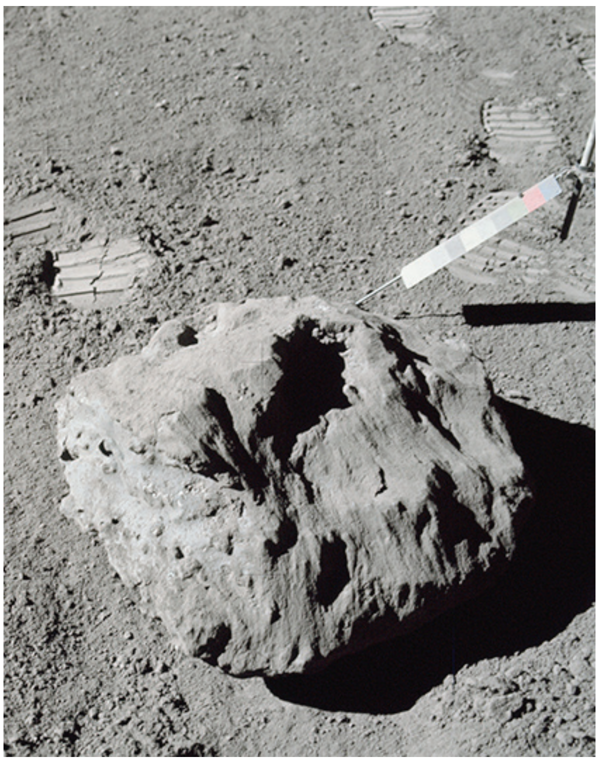

Figure 3. Context image of the Station 8 boulder (AS17-146-22370) after it had been rolled over. Left face of the boulder is the source of samples 78235-6, and 8 [12].

Implications for Future Robotic Exploration of the Moon: If the Station 8 boulder is indeed derived from the Sculptured Hills there are implications for how a robotic explorer on the Moon could sample unique compositions and what instruments would be useful in identifying such samples.

Crater central peaks and walls have long been known to contain a rich diversity of materials [e.g., 3, 4, 14] and boulders from such outcrops are readily identified in high-resolution LROC images. However, the resolution of M^3 data limits the detection of smaller scale outcrops. A rover investigating the base of a peak or crater slope could encounter a number of boulders, if such a rover contained a high-resolution imaging spectrometer it could differentiate unique samples derived from upslope or, in the case of Station 8, nearby.

Conclusions: The combination of remote sensing data (from M^3) and sample composition and location information (from Apollo and LROC) suggest that even for samples that lack details that point to their origin such as a boulder track absent from the Station 8 boulder [12], their origin might be inferred. While additional work is necessary to more confidently identify the origin of the boulder (including detailed spectral measurements of samples of the boulder and compositions inferred from M^3 data), it is clear that any future mission will benefit from the wealth of data from multiple instruments.

References:

[1] Boardman, J. W., et al., (2011) *Journal of Geophysical Research*, 116,
[2] Green, R. O., et al., (2011) *J. Geophys. Res.*, 116, E00G19.
[3] Pieters, C. M., et al., (2011) *Journal of Geophysical Research*, 116,
[4] Dhingra, D., et al., (2011) *GRL*, 38, 11201.
[5] Klima, R. L., et al., (2011) *Journal of Geophysical Research*, 116,
[6] Isaacson, P. J., et al., (2011) *Journal of Geophysical Research*, 116,
[7] Mustard, J. F., et al., (2011) *Journal of Geophysical Research*, 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)
[13] Jackson, E. D., et al., (1975) *GeoL Soc. Am. Bull.*, 86, 433-442.
[14] Cahill, J. T. S., et al., (2009) *Journal of Geophysical Research*, 114, 09001.