

COMPOSITIONAL VARIABILITY AND BASALT STRATIGRAPHY OF THE TAURUS-LITTROW VALLEY FLOOR: IMPLICATIONS FOR DOUBLE CORE TUBE 73001/02. N. E. Petro (Noah.E.Petro@nasa.gov)¹, D. P. Moriarty^{1,2}, H. H. Schmitt³, C. Shearer⁴, L. Sun⁵, ¹NASA GSFC, ²University of Maryland College Park, ³University of Wisconsin-Madison, ⁴Institute of Meteoritics, University of New Mexico, ⁵Hawai‘i Institute of Geophysics and Planetology, University of Hawai‘i at Mānoa.

Introduction: The Apollo 17 mission collected a diversity of materials from across the Taurus-Littrow Valley, much of which have been studied in detail for nearly five decades [1-3]. Recently a number of orbital missions have mapped the Moon in unprecedented detail, generating an enormous volume of data and derived products including mineralogy [4]. With these new datasets we have an opportunity to revisit interpretations of the geology of the Apollo 17 site [3] as well as use the remotely sensed data to support the analysis of “new” lunar samples. A set of samples was set aside for future study enabling modern analytical techniques to examine “pristine” samples, including the double core tube collected at Station 3 (73001/73002) [5]. The ~70 cm deep core sample was collected within a landslide deposit (the “light mantle”) near the surface exposure of a lobate scarp [1, 6, 7]. These new samples afford a unique opportunity to use remotely sensed data and an understanding of geologic processes to predict what could have been sampled in the core.

Here we focus on estimated abundance of olivine across the valley floor [4] to characterize basaltic stratigraphy of the landing site, similar to the sample analysis for the Apollo 11 and 12 sites [8]. Prior analyses of the composition of the valley utilized Clementine UVVIS and Moon Mineralogy Mapper (M³) data to characterize compositional variability in the valley [3, 9,

the composition of the basalt fill, apart from down-slope mixing between the surrounding massifs and basalt fill. Using the Kaguya Multi-Band Imager (MI) estimates of olivine integrated with Moon Mineralogy Mapper hyperspectral image cubes, we will explore olivine variation in rock and regolith samples across the valley floor and use that as an indication of multiple lava flows at the Apollo 17 site. Knowing that we will have the opportunity to identify additional fragments of basalt in 73002/73001, we can anticipate their compositions from the MI data.

Apollo 17 Sample Data – Olivine Abundances:

Detailed analyses of the abundance of olivine in regolith and rock samples [10-12] provides the reality of basaltic variability across the valley floor. Brown et al. [12] use variations in olivine abundance in rock fragments to differentiate two primary groups of basalts, those that have olivine (Type I) and those that do not (Type II). The Type I basalts were split into groups based on cooling rate. Type 1 and 2 basalts also appear to represent melts that experienced different degrees of fractional crystallization, low olivine rocks are lower in MgO and TiO₂ suggesting they are further down a liquid line of descent with removal of olivine during crystallization [13]. Of the fragments from all stations visited by the crew analyzed by [12], the only Type II fragments were collected at Station 5 (Camelot Crater, samples 75035

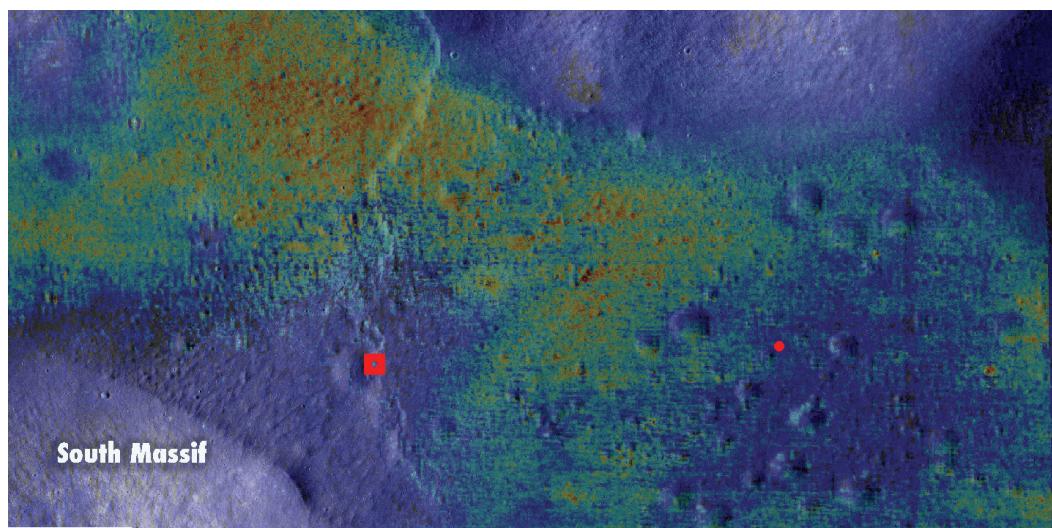


Figure 1. Kaguya MI map of olivine [4] in the Taurus-Littrow Valley floor, with the locations of the LM (red point) and Station 3 (red box) marked. White line at bottom left is a 2 km scale bar. Color indicates olivine abundance, from ~5% in blue to ~40% in red.

In regolith samples, the abundance of olivine does not have as broad a variation in abundances as observed in the rock fragments [10, 11]. Jolliff [10] reported the normative mineralogy of the <1mm size fraction, while Heiken and McKay [11] reported the petrography of the 90-150 μm fraction of soils from each sampling station and Lunar Roving Vehicle sample (quickly collected regolith samples from the rover). In the <1mm size fraction, the normative abundance of olivine varies from ~3.6% (LRV12) to 24.2% (Orange Glass at Station 4). In the 90-150 μm fraction abundances were far more limited, from 0% to 1.1% [11].

Of relevance to the ongoing study of the Station 3 core is the single basalt fragment collected at the Station (73219), a single 2.88 g high-Ti basalt fragment [14]. Analysis of the fragment [15, 16] showed that it contains ~3.5 wt % olivine, similar to samples 72115 (3.5%) and 74255 (3.2%) [12].

Remote Assessment of Olivine: The Kaguya MI estimate of olivine (Figure 1), allows for an investigation into the distribution across the Taurus-Littrow Valley floor. The estimate of olivine abundance is based on a radiative transfer model using over 92,000 spectra [4]. For olivine, the position of a multiple overlapping absorption features near 1 μm [17] is the diagnostic absorption feature to determine the presence and abundance of the mineral.

The map in Figure 1 shows that there is indeed variability in olivine abundance across the valley, driven by, what appears to be two geologic features. First, the younger of the light mantle deposits [3] have masked the apparent olivine abundance on the valley floor and is <~10%. Secondly, the central cluster [1, 6] has a similarly subdued olivine abundance. Outside of these two units, there is a general enhancement of 20-40% across the valley floor.

What is Driving Olivine Variations Across the Valley Floor?: The olivine distribution shown in Figure 1 suggests that the central cluster as a reduced abundance of olivine and that areas outside the cluster have significantly enhanced abundances, at values that are unrepresented in the sample collection. This variability raises several questions:

Has the central cluster exposed a distinct basalt flow/unit? The central cluster and its craters may have exposed a subsurface low-olivine abundance flow, and soils sampled at the LM/Station 10, Station 9, Station 1, and Station 5 reflect this unit, classified as Type I by [12]. The fragments sampled outside this region reflect a distinct unit, some of which might be preserved within the Station 3 core.

Additional basalt fragments in the Station 3 core will help constrain what, if any, regional variations occur in the area of the light mantle. A comparison of basalt

fragments at Stations 2 and 4 with those found at Station 3 will help identify what, if any, distinct characteristics may be found in basalts from outside the central cluster.

Are there regolith properties that are influencing the spectral signature? Data from other orbital instruments suggest that the central cluster has a higher abundance of rocks and a distinct surface texture [7]. We know that surface texture and rock abundance influence reflectance spectra, and that the presence of glass and/or ilmenite can be interpreted as olivine in near infrared spectra [19]. Disentangling these influences on the spectra will be critical for interpreting the abundance of olivine (or other minerals) at any location on the lunar surface.

Implications for 73002/73001: Basalt fragments at Station 3 are rare (see above). While it is known that there are rock fragments in the upper core (73002), and a preliminary analysis suggests one of those fragments may be a basalt, there is an expectation that more fragments will be found in the lower portion of the core (73001) [7]. If additional fragments are indeed found, understanding the abundance of olivine in those samples will add important datapoints in understanding the distribution of olivine in the valley floor. Similarly, a profile of the abundance of olivine (as well as other minerals) along the core will potentially reveal any stratigraphy or sorting within the deeper portions of the landslide deposit.

Conclusions: The distribution of olivine in the Taurus-Littrow valley suggests that both the emplacement of the light mantle deposits [3] and the central cluster [1, 6] have subdued the abundance of olivine. New basalt fragments identified in the Station 3 core tube will help better understand regional variations in olivine abundance. Sample data from elsewhere in the valley also affords an opportunity to better interpret the factors that control near-infrared spectra.

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References: [1] Wolfe, E. W., et al., (1981) The Geologic investigation of the Taurus-Littrow valley, Apollo 17 landing site, 45, [2] Korotev, R. L., et al., (1992), 22, 275-301. [3] Schmitt, H. H., et al., (2017) *Icarus*, 298, 2-33. [4] Lemelin, M., et al., (2016) LPSC 2016, 2994. [5] Shearer, C. K., et al., (2019) LPSC 2019. [6] Parker, R. A., et al., (1973) Apollo 17: Preliminary Science Report, SP-330, [7] Petro, N. E., et al., (2020) AGU 2020, 2234. [8] Schmitt, H. H. and R. L. Sutton, (1971) Stratigraphic Sequence for Samples Returned by Apollo Missions 11 and 12, LPSC II, 197. [9] Robinson, M. S. and B. L. Jolliff, (2002) *JGR-Planets*, 107k, 20-21. [10] Jolliff, B. L., (1999) *JGR*, 104, 14123-14148. [11] Heiken, G. and D. S. McKay, (1974) *PLPSC*, 5, 843-860. [12] Brown, G. M., et al., (1975) *PLPSC*, 1, 1. [13] Longhi, J., (1992) *GCA*, 56, 2235. [14] Ryder, G., (1993) Catalog of Apollo 17 rocks, 94, 24058. [15] Warner, R. D., et al., (1976) *PLPSC*, 15. [16] Warner, R. D., et al., (1975) *PLPSC*, 1, 193. [17] Isaacson, P. J. and C. M. Pieters, (2010) *Icarus*, 210, 8-13. [18] Moriarty, D. and N. E. Petro, (2019) AGU 2019, P31C-3445. [19] Moriarty, D. and N. Petro (2020), LPSC 2020.