EXPLORING A LUNAR LANDSLIDE DEPOSIT IN THE TAURUS-LITTROW VALLEY (TLV). VARIATIONS IN MINERALOGY AND MINERAL VOLATILE TRAPS.

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Introduction: The double drive tube core sample (73001/73002), collected at Station 3 during the Apollo 17 mission, penetrated a lunar landslide deposit that was transported from the slope of the South Massif into the TLV (Figure 1). Orbital data suggest that this deposit represents multiple events that were triggered by movement along the Lee-Lincoln scarp [e.g., 1] or impact events [e.g., 2,3]. Although numerous core and trench samples were collected during the Apollo program and numerous landslide deposits have been identified on the lunar surface by orbital missions [e.g., 3], the Station 3 double drive tube is the only core that penetrated a landslide deposit. The intentions of our study are: to establish the stratigraphy of the deposit; to better understand the processes at work during the event(s), including the role of volatiles in the event (e.g., fluidization-enabled flow, escape of fluidizing volatiles) [1] and the capability of deposits for trapping indigenous volatiles; the number of landslide events; and the trigger(s) of such events. Here, we report some initial petrologic observations of the < 1mm fraction of the regolith. A companion abstract [4] emphasizes <1 mm lithic fragments, compares them to surface lithologies, and to > 4 mm lithic fragments.

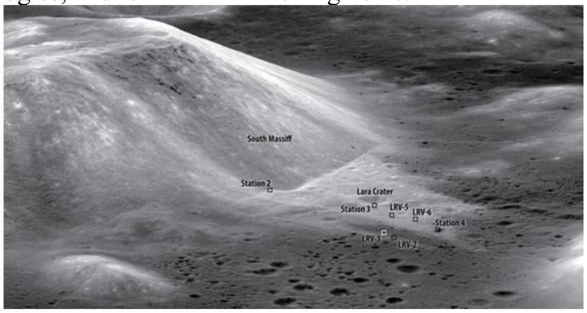

Fig. 1. LROC-LRO images of the Taurus-Littrow Valley (TLV) landslide deposit that includes the of location of station 3 and the 73001/2 core in the light mantle deposit.

Analytical Approach: Samples received were from 0.5 cm depth intervals from the first pass during dissection of 73002, the upper segment of the double drive tube. As of January 4th, 2021, samples examined in this study and their locations in the core are illustrated in Figure 2. Part of the dissection process of pass 1 included sieving the samples (except the rind) into two fractions (< 1 mm, > 1mm). For our study we split larger allocated sample masses for petrography and stable isotope analysis (H, O, Cl, S), whereas small sample masses were used only for petrography. At the University of New Mexico (UNM) all samples designated for petrography were then further sieved into 5 size fractions: <20 µm, 20-90 µm, 90-150 µm, 150-250 µm, and 500-1000 µm size. Only the rind sample was sieved for size fractions greater than 1 mm. The different size fractions were mounted on glass slides for microbeam analysis. We collected backscattered electron (BSE) images, quantitative EDS analyses and X-ray maps with a TESCAN Lyra3 SEM. Modal mineralogies are being estimated for each size fraction. After imaging and analysis, individual fragments were selected for analysis using a JEOL 8200 electron microprobe. All analyses were done at the UNM.

Results: An important observation made during core extrusion and the preliminary observation process was that the core got compressed during extrusion, and remained more friable during dissecting compared to other lunar cores [5]. Figure 2 places the samples within the context of micro-X-ray Computed Tomography (micro-XCT) imaging of 73002. The <1 mm fines comprise between 67 and 97% of each 0.5 cm depth interval of the core (Fig. 2). The 1-4 mm fragments make up between 2.9 and 13.8 wt% of each core segment. These measurements were made during the preliminary examination of the core by the JSC lunar curation staff and the ANGSA Preliminary Examination Team. Our preliminary results are limited to the 90-150 µm size fraction. Images of various components making up this size fraction are illustrated in Figure 3. Lithic fragments within this size fraction include basalts (e.g., Fig. 3E and 3F), regolith breccias (Figure 3E), Mg-suite lithologies (Fig. 3E), impact melts, impact melt breccias, and "evolved" lithologies (e.g., sodic plagioclase, Fe-rich pyroxene, zircon, SiO_2). Preliminary observations of the <2 mm lithic fragments are reported by [4] and XCT analyses of the >4 mm lithic fragments are presented by [6]. Individual mineral fragments (e.g., spinel, plagioclase, pyroxene, zircon) appear to reflect the lithic fragment populations. Both impact (Fig. 3C) and high-Ti volcanic (Fig. 3D) glasses are found in the 90-150 µm size fraction. The volcanic glasses appear to be dust-coated to some degree, but also exhibit micro-mounds of sublimates. Agglutinates (Fig. 3A,B) of various sizes are common throughout the landslide. Initial estimates of their modal abundance indicate a range that may be attributed to different levels of maturity and should correlate with I_s/FeO. For example, 73002,163 (90-150μ) contains approximately 15% agglutinates whereas the same size fraction for other soils in the deposit contain greater than 40% agglutinates.

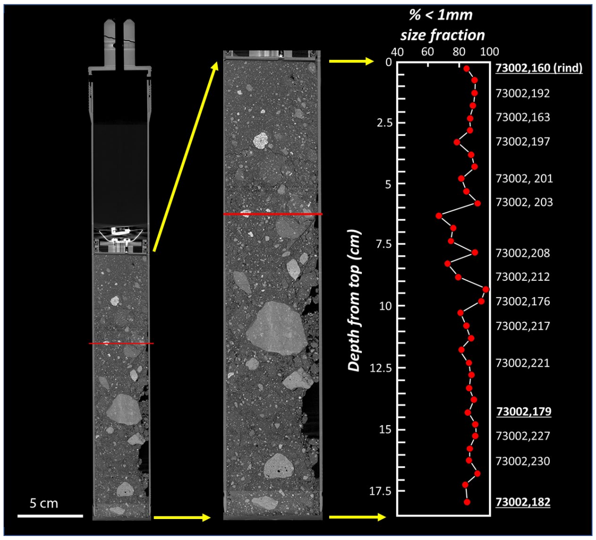

Fig. 2. Location of samples for this study are placed within the context of the XCT imaging of core 73002 and % < 1mm components (from preliminary examination observations). The latter data is derived from the first pass of the core. The final extruded 73002 core is slightly more compressed. The underlined samples represent those used for stable isotope analyses (H, O, Cl, S).

Discussion: We are in the process of determining the stratigraphy based on grain size, mineralogy, and agglutinate content. These data will be combined with I_s/FeO and major- and trace-element chemistry to gain a full perspective of the origin and evolution of the landslide stratigraphy. The friable and compressible characteristics of the landslide core is distinct from other Apollo cores previously processed [5]. Some of these characteristics may be due to the void space that was documented in the XCT image (Fig. 2). It has been suggested that volatiles enable landslide dynamics and that escaping of fluidizing volatiles may be partially responsible for transport of fine material in the landslide column [1]. Our examination of grain size and modal mineralogy of 73002 will allow us to address this issue. The lower portion of the core (73001) will provide further insights into this process.

Several groups will conduct bulk and mineral phase analyses of traditional (H, O, S) and non-traditional (e.g., Cl, K, Cu, Zn) stable isotopes of volatile elements. The mineralogy presented here identifies potential mineralogical reservoirs of volatiles in the regolith to better interpret the stable isotope measurements. For example, Cl may reside in the apatite associated with lithic fragments, micro-mounds on volcanic glasses, and products of impact melting (e.g., glasses, agglutinates) and regolith gardening.

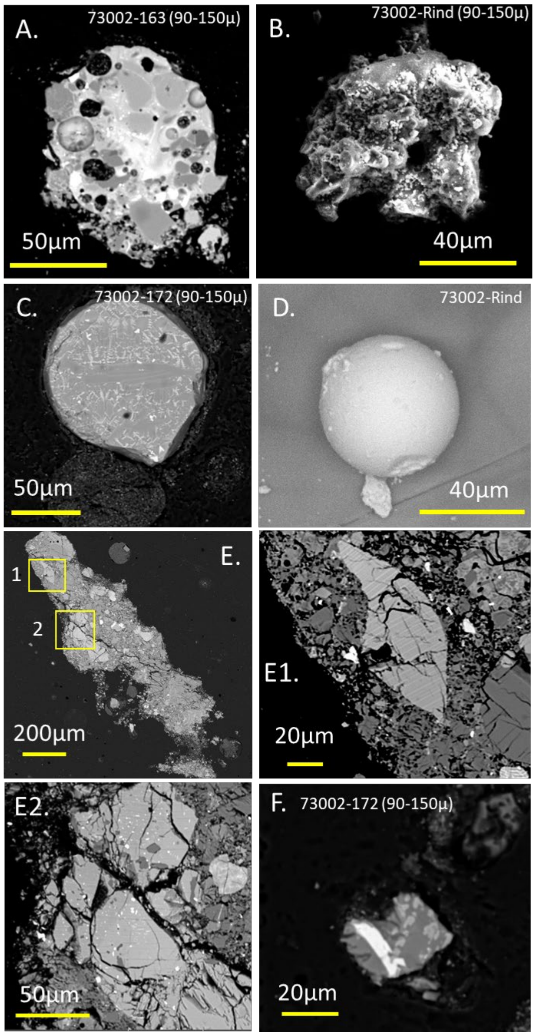

Fig. 3. Examples of the mineralogy of 90-150 μm and >1 mm size fractions in select samples. A. BSE image of an agglutinate. B. Electron micrograph of an agglutinate. C. BSE image of a devitrified impact glass bead. D. Electron micrograph of volcanic glass bead with splatter and perhaps micro-mound coatings [e.g., 7]. E. Regolith breccia with a variety of mineral and lithic fragments. E1. Pyroxene with fine exsolution lamellae. E2. Pyroxene-rich, plagioclase-poor lithic fragment. F. High-Ti (ilmenite) mare basalt.

***References*:** [1] Schmitt H. (2017) *Icarus 298*, 2-33. [2] Arvidson R. et al. (1976) *Proc. LPSC* 7, 2817-2832. [3] Bickel V. et al. (2020) *Nature Communications*, *11*(1), 1-7. [4] Simon S. et al. (2021) *52nd LPSC in press.* [5] McKay D. et al (1991) In *Lunar Sourcebook*, 285-356. [6] Jolliff B. et al. (2021) *52nd LPSC in press.* [7] Heiken et al. (1974) GCA 38, 1703-1718.

***Acknowledgments*:** This work was funded by NASA ANGSA grant **80NSSC19K0958** to CKS.