APOLLO 17 DRIVE TUBE 73002 MAJOR AND TRACE ELEMENT CHARACTERIZATION.

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Introduction: The recent opening and dissection of Apollo 17 double drive tube 73001/73002 (Station 3, Figs. 1,2) as part of the Apollo Next Generation Sample Analysis (ANGSA) program has generated renewed excitement as scientists are beginning to analyze pristine lunar samples with modern instrumentation. Careful characterization of core geochemistry and lithologic components will be used to test hypotheses for the origin of the Light Mantle (Fig. 1) and evaluate components in context of known Apollo 17 materials.

As part of the Consortium for the Advanced Analysis of Apollo Samples (CAAAS), team members at Washington University in St. Louis are part of the group determining major, minor, and trace-element compositions over the length of the core. In this abstract we report preliminary results for the first six samples allocated to us from the 1st dissection pass (0.5 cm depth intervals) of the 18.5 cm unsealed (upper) drive tube 73002. We compare the compositions from 73002 with one of the trench soils 73261 (see also [1]). We model Apollo 17 lithologic components indicated by these compositions following the approach of [2].

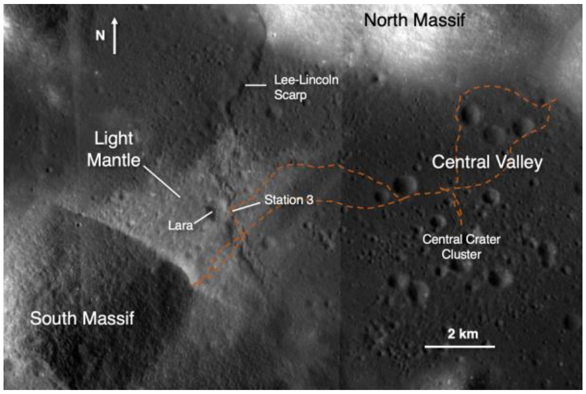

Figure 1. Apollo 17 Sta. 3 location in the "Light Mantle" at the foot of South Massif and east of Lara crater. LROC NAC (Narrow Angle Camera) mosaic (NASA/GSFC/ASU).

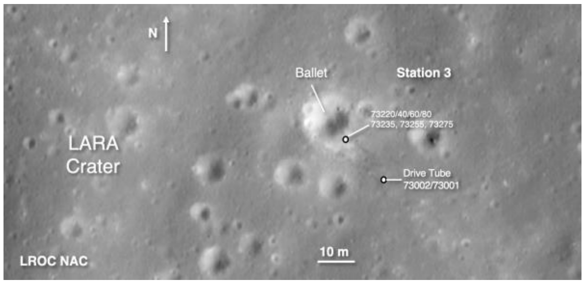

Figure 2. Close-up, LROC NAC image of Sta. 3, showing locations of drive tube 73002/73001 and the Sta. 3 trench.

Methods: Six subsamples of 73002 were analyzed. The samples are sieved (<1 mm) material from intervals 1, 5, 11, 20, 29, and 36. Interval 1 is the upper half cm interval (rind) and 36 is the bottom interval, 17.5-18.0 cm below the surface (Table 1). We have been allocated an additional 17 samples from the lower part of 73002, below 8.5 cm, and these will be reported at the conference. Aliqouts of 50 mg were received from NASA for major and trace element analysis by ICP-MS and major element analysis by electron microprobe (fused beads, FB-EPMA). Approximately 40-45 mg of each sample was dissolved in a mixture of double-distilled HNO_3 and HF on a hotplate at ~120 ºC for several days. Elemental concentrations were determined using a quadrupole-ICP-MS (Thermo Fisher Scientific iCAP Qc) at Washington University in St. Louis. The instrument was calibrated using a series of USGS reference materials of known concentrations. Appropriate dilution factors were used such that concentrations of individual element were in the range required for measurement in analog mode. For each ICP-MS session and before sample analysis, a series of autotuning and performance reports were conducted after the instrument had stabilized over a few hours of running. An internal standard of 5 ppb indium was used for signal drift corrections.

Table 1. Measured sections of drive tube 73002

Sample number	Depth beneath the surface [cm]
73002, 160	0 – 0.5
73002, 162	2.0 – 2.5
73002, 173	5.0 – 5.5
73002, 174	9.5 – 10.0
73002, 177	14.0 – 14.5
73002, 180	17.5 – 18.0

Results: Measurements of the six samples reveal compositions that are very similar to previously measured Station 2 and Station 3 samples. Here we compare the 73002 core subsamples with one of the Station 3 trench soils, 73261, which we also analyzed for this work. Soil from the top of the core (73002,160 and 73002,162) is very similar in chemical composition to 73261 (the four trench samples are very similar to one another in chemical composition [3]). Samples from deeper in the core show consistent variations in most elements, but decreases occur with depth in the concentrations of Fe, Cr, Ti, and Sc (Fig. 3). These elements are largely contributed by high-Ti mare basalt and orange volcanic glass. The compositions deeper in the core, below 5 cm, are more like the more feldspathic compositions of Station 2 and 2A (LRV-4) soils [2].

Discussion: To place the compositions of 73002 samples into context, we carried out a mixing analysis following the approach of [2]. The compostions of the Station 2 and 3 soils can be reasonably well accounted for using six mixing components: Apollo 17 high-Ti mare basalt (HT), a very-low-Ti basalt composition (LT), orange volcanic glass (OG), noritic impact-melt breccia (NB), an anorthositic norite composition (AN), and a small carbonaceous chondrite (CI) composition. Using an error-weighted, linear-least-squares approach that minimizes the sum of squares of residuals [2], the average of the upper two samples is best fit as a mixture of ~10% HT, 0.9% LT, 0.2% OG, 41% NB, 46% AN, and 0.7% CI. This component mix is similar to what [2] found for average Station 3 soil. The two samples toward the middle of 73002 (~5 and 10 cm) are best fit by 5% HT, 40% NB, 52% AN, and 0.4% CI. The lower two samples (14 and 18 cm) are best fit with 3% HT, 37% NB, 55% AN, and 0.4% CI. It appears from these samples that the mare basalt component decreases with depth, NB decreases slightly, and the AN component increases. Also, with depth, the goodness of fit of the mixing results decreases.

The AN component is complex and is meant to represent the non-basaltic and non-impact-melt breccia materials of the highlands massifs at Apollo 17. Korotev and Kremser [2] described this component as a mixture of materials that have an average composition similar to the "anorthositic gabbro" (AG) composition of Rhodes et al. [4], which likely includes a wide range of compositions that such as granulitic breccias, feldspathic breccias, and a diversity of lithic clast types separated from the Apollo 17 noritic impact-melt breccias when they break down. Korotev and Kremser [2] used the composition of disaggregated regolith breccia 73131 to model this component, assuming the breccia consisted only of AG and NB (the poikilitic impact-melt breccias that compose many of the Apollo 17 boulders are compositionally rather uniform), and optimized this component's for the soils with a South Massif component. The derived composition is actually that (normatively) of anorthositic norite (AN). In reality, this component is quite variable and consists of a wide variety of lithologies (see [5]). One of our ongoing objectives is to analyze core soil intervals and lithic clasts, geochemically and petrographically, to better understand the variety of lithic clasts in the core and their relationship to the ancient upper crust of this part of the Moon. Among these materials, we may expect to find lithic or glass components that represent Tycho ejecta, if in fact debris from Tycho, evidenced by secondary impacts on South Massif and possible impact-melt deposits at the crest of the South Massif, caused the landslide.

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References: [1] Jolliff B. L. et al. (2020) *Lunar Planet Sci.* **51** #1970. [2] Korotev, R. L., and D. T. Kremser (1992) *Proc. Lunar Planet. Sci.* **22**, 275-301. [3] Meyer, C. (2012) Lunar Sample Compendium. [4] Rhodes, J. M., et al. (1974) *Proc. Lunar Sci. Conf. 5th*, 1097-1117. [5] Simon, S. B., et al. (2021) *Lunar Planet. Sci*. **52**, #1562.

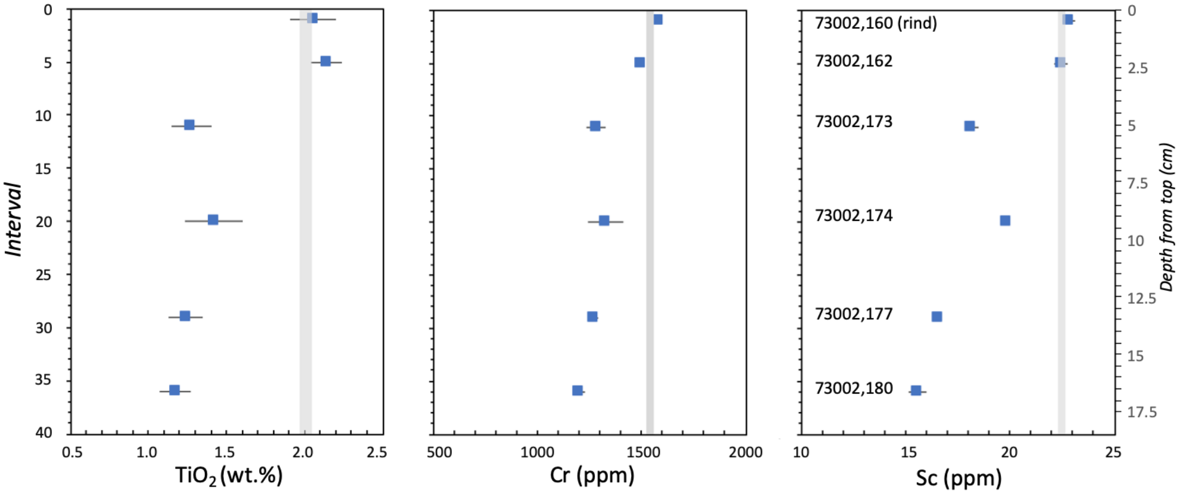

Figure 3. Preliminary analyses of a subset of 73002 regolith intervals showing a decrease in mare basalt components with depth. The gray bar represents the composition of 73261,71 trench soil (our analysis).