Multispectral Imaging and Hyperspectral Profile of the First Dissection of Core 73002. L. Sun[1], P. Lucey[1], A. Flom[1], C. Ferrari-Wong[1], R. Zeigler[2], J. Gross[2,3], N. Petro[4], C. Shearer[5], F. M. McCubbin[2] and The ANGSA Science Team [1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA, lzsun@higp.hawaii.edu, [2]Astromaterials Acquisition and Curation Office, NASA Johnson Space Center, Houston, TX 77058, USA. [3]Rutgers State University of New Jersey, Department of Earth & Planetary Sciences, Piscataway, NJ 08854, USA, [4]Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA, [5]Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, USA

Introduction: The double drive tube 73001/2 was collected at Station 3 during EVA 2 of Apollo 17 mission, located near the rim of Lara and Ballet craters, on the light mantle in the southwest of the Taurus-Littrow valley [1-3]. Core 73002 is the upper segment, and it sampled about 20 cm; core 73001 is the lower segment, and it has been preserved under vacuum since its return. On November 5, 2019, the Apollo Next Generation Sample Analysis (ANGSA) team extruded core 73002, and thus beginning the examination of the first of the two double drive tube core samples. As part of the preliminary examination, spectral imaging scanning and hyperspectral measurements of the cores are being carried out by the University of Hawaii, supported by the CAAAS (Consortium for the Advanced Analysis of Apollo Samples) team of ANGSA and the curatorial facility. In this work, we present preliminary results of spectral data obtained during the first dissection pass of core 73002 [4].

Methods: The multispectral imaging camera used to document the core covers six wavelengths (Table 1), including some of the bands used by the Clementine UVVIS camera, LRO WAC and KAGUYA Multiband Imager. The spatial resolution is ~ 60 μm/pixel. The hyperspectral profiles were acquired by an Analytical Spectral Devices (ASD) spectrometer, with wavelengths covering 500 – 1700 nm at 10 nm spectral resolution, overlapping M^3 from Chandrayaan-1, the Spectral Profiler on board Kaguya, and the large lunar soil spectral datasets measured at RELAB. In the future, hyperspectral profiles will be obtained at 1 mm spatial resolution during the dissection process to provide hyperspectral data throughout the whole core volume.

Currently all the spectrometers at the curation facility observe through the safety glass on top of the glove cabinet, which limits the detection range of spectroscopy to visible and near IR wavelengths. However, when the core dissection reaches the final dissection pass is complete, the core will be moved outside of the pristine sample handling cabinet, making it available for inspection at longer wavelengths. We plan to collect data from 2.5 to 14 μm at 10 mm spatial resolution at this time.

To establish measurement methodologies, we carried out preliminary spectral imaging and hyperspectral measurements during the first dissection pass of the core using existing instrumentation. Spectral imaging was obtained at wavelengths listed in Table 1 at a 15° incidence angle, 10° emission angle, and a 25° phase angle in plane. The full field of view (FOV) of the imaging system is 47 mm × 36 mm at 62.5 μm/pixel resolution. However, the available spectral illuminator did not cover the entire core width, and the illuminated area was a roughly 30 mm-diameter circle within the image frame, so the preliminary data set has a FOV of 30 mm.

Hyperspectral profile was obtained from 500 nm to 1700 nm wavelengths (data beyond 1700 nm is not usable due to low signal to noise ratio from a combination of low spectral irradiance from the illuminator and low sensitivity of the spectrometer at longer wavelengths). Spectra were calibrated relative to a Teflon standard.

Table. 1 Preliminary and operational parameters*

Spectral imaging system	Hyperspectral profiles
Wavelengths (nm): 415, 570, 750, 900, 950, 990	Wavelengths (nm): (P) 500 – 1700; (O) 500 – 2500; (F) 500 – 14000
Viewing Geometry: (P) i=15, e=10; (O) i=0, e=15	
FWHM: 10 nm	Spectral resolution: 10 nm
Spatial resolution (μm /pixel): (P) 62.5, (O) 10	Spatial resolution: (P, F) 10 mm, (O) 1 mm
FOV: (P) 30 mm × 30 mm; (O) 47 mm × 36 mm	Sampling intervals: (P) 10 mm, (O)1 mm, (F) 5 mm
Coverage: full coverage of the whole core	Coverage: (P) profile along center, (O, F) 4×20 images

*P-Preliminary, O-Operational, F-Final dissection pass

Multispectral results: Fig. 1a is a photograph of core 73002 during the first dissection pass, and the arrow points to the dissection progress. For the multispectral results, the 570 nm reflectance image (Fig. 1b) shows systematic darkening from bottom to top of the core, and the false colored image (R=750 nm/415 nm, G=750 nm/950 nm, B=415 nm/750 nm) in Fig. 1c shows that soils closer to the surface tend to be spectrally redder. Both of these observations suggests an increasing maturity with decreasing depth along the core, while we don't observe strong systematic variations in multispectral color along the core.

We calculated the content of FeO, TiO_2 and optical maturity (OMAT) of the core using the color ratio method of Lucey et al. (2000) [5], and the compositional profiles are shown in Fig. 2. The abundance of FeO and TiO2 has little variation along the core, suggesting a homogeneous composition of the whole core. OMAT increases with depth, indicating that the regolith maturity decrease with depth. We observe a relatively high maturity zone at the top 14 cm, and this may be due to the local regolith reworking. It takes about 61 million years to achieve this 14 cm regolith reworking depth based on the equation of Morris (1978) [6].

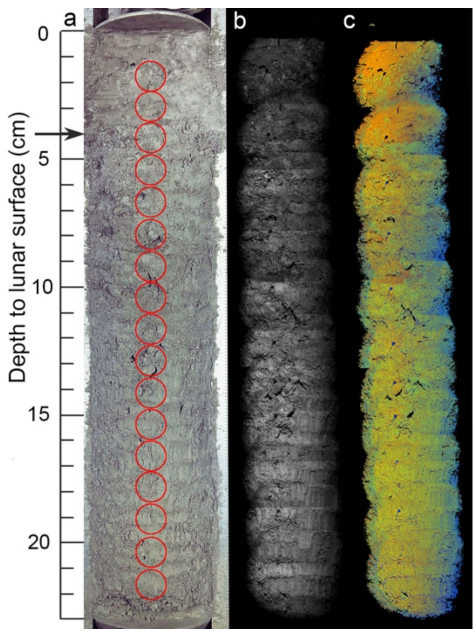

Fig. 1 Core 73002 images during the first dissection. (a) Photograph of the core, red circles are hyperspectral profile footprints, the scale is shown on the left, and the arrow indicates dissection progress. (b) 570 nm reflectance. (c) false colored image of the core, R=750 nm/415 nm, G=750 nm/950 nm, B=415 nm/750 nm.

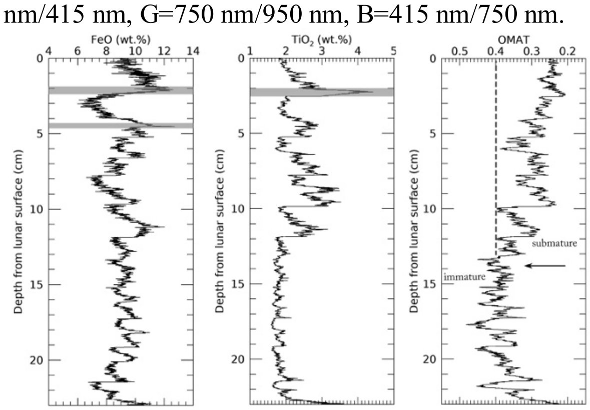

Fig. 2 FeO, TiO_2 and OMAT profile along the core.

Hyperspectral results: For the hyperspectral profile, we measured 17 spots along the center of the core at 1 cm intervals (areas circled out in Fig. 1a). The reflectance spectra are shown in Fig.3. The locations are indicated by the scale next to the core in Fig. 1a. Reflectance spectra in Fig. 3a and b show that the soils closer to the surface have lower reflectance and steeper slop from visible to near infrared wavelengths, indicating a systematic darkening and reddening effect along the core, consistent with the multispectral imaging results. No systematic variation of the absorption depth at one micron is observed from the continuum removed spectra in Fig. 3c, which may be due to the non-uniform grain sizes variation of soils along the core.

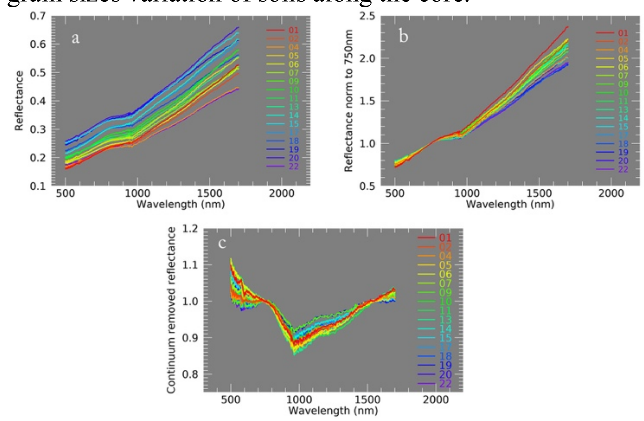

Fig. 3 (a) Reflectance spectra along the core, (b) spectra scaled at 750 nm, and (c) continuum removed spectra.

Conclusions and future work: We report the compositions and mineralogy of core 73002 based on spectral data measured from outside of the sealed glovebox. This spectroscopy method has great potential to be applied on future extraterrestrial sample return.

For future measurements, to suppress the shadowing effect, we will make a custom illuminator that provides illumination at the full width of the core for the imaging after each dissection pass. The use of the 15° incident angle and 25° in plane phase angle in the preliminary data resulted in substantial shadowing at the ~100 μm scale, thus the preliminary spectral imaging data set will be confined to spectral ratios lacking pixel level photometric correction. To mitigate this, the operational data will be obtained with a zero degree incidence angle to minimize shadowing, and a viewing angle of 15°.

References: [1] Butler P. (1973), MSC 03211. [2] Allton J. H. (1989), JSC-23454, pp97,Curator's Office, JSC. [2] Duke M.B. and Nagle J.S. (1976), JSC09252 rev. Curators' Office. [4] Krysher et al., (2020), 51th LPSC, Abstract #2989. [5] Lucey P. et al., (2000) JGR 15(E8). [6]Morris R. (1978), 9th LPSC, pp2287-2297.