Multispectral Imaging and Hyperspectral Profile of the First Dissection for Core 73002. Lingzhi Sun[1], Paul Lucey[1], Abigail Flom[1], Charles Shearer[2], Ryan Zeigler[3], Juliane Gross[3] [1]Hawai'i Institute of Geophysics and Planetology, Dept. of Earth Sciences, University of Hawai'i at Mānoa, 1680 East-West Rd. Honolulu, HI 96822, USA, lzsun@higp.hawaii.edu, [2]Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131, USA, [3]Astromaterials Acquisition and Curation Office, NASA Johnson Space Center, Houston, TX, 77058 USA.

Introduction: The double drive tube 73001 and 73002 were collected at Station 3 during the EVA 2 of Apollo 17 mission, located near the rim of Laura crater, on the light mantle southwest of 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 curated under vacuum since its return. In December 2019, the Apollo Next Generation Sample Analysis (ANGSA) team opened core 73002, beginning to examine the first of the two pristine 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 will be presenting some preliminary results of imaging obtained during the first dissection of core 73002.

Methods: The multispectral imaging camera 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 about 60 μm/pixel. The hyperspectral profiles are acquired by an Analytical Spectral Devices (ASD) spectrometer, with wavelengths covering 500 – 2500 nm at 10 nm spectral resolution, substantially overlapping M^3 from Chandrayaan-1, the Spectral Profiler on board Kaguya, and the large lunar soil spectral datasets measured at RELAB. Ultimately, the 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 observe through the safety glass on top of the glove cabinet at the curatorial facility, which limits the detection range of spectroscopy to visible and near IR wavelengths. However, when the core dissection reaches the bottom layer, 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 for this layer of the cores.

To establish measurement methodologies, we carried out preliminary spectral imaging and hyperspectral measurements during dissection of the first layer 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 that will be cross calibrated to Spectralon.

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 layer

Preliminary Results: Fig. 1 shows images of the whole core 73002 during the first dissection. The upper side of the images is closer to the surface side on the Moon, and the arrow in Fig 1a marked the dissection progress at the time of the data collection. The images show very fine grained lunar regolith. 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 them suggesting an increasing maturity with decreasing depth along the core, while we don't observe strong systematic variations in multispectral color along the core.

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.2. The distances are indicated by the scale on the core receptacle inside the curation box, and larger numbers are closer to the surface side shown in Fig. 1a. Reflectance spectra in Fig. 2 show that the soils closer to the surface have lower reflectance, indicating a systematic darkening effect along the core, consistent with the multispectral imaging results.

Fig. 3 shows the variation of 750 nm reflectance, 1550 nm/750 nm ratio and absorption depth at 1000 nm along the core. The reflectance at 750 nm increases with depth, while the ratio of 1550 nm/750 nm decreases with depth, both indicating a decrease of maturity with depth. While there are strong variations in the 1000 nm absorption depth of Fe^{2+} along the core, but we don't observe a coherent variation with depth. Our visible and near IR spectral data show a systematically darkening and reddening effect with depth due to space weathering. Possible reasons for the band depth variation could be: 1) the grain sizes of soils along the core are not uniform, and the soil grains might become coarser from top to bottom; 2) there might be compositional variations along the core, as the presence of mafic minerals can affect absorption depth.

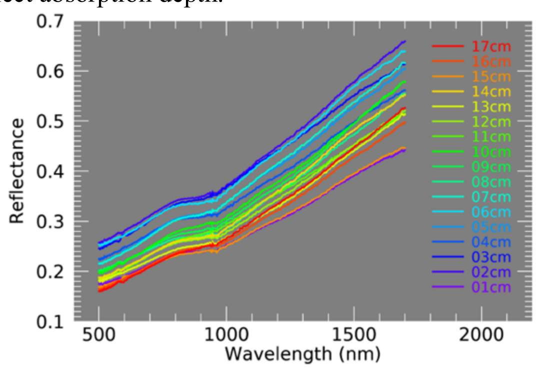

Fig.2 Reflectance spectra along the core, and the centimeter values refer to the scale shown in Fig. 1a.

Future Work: We are completing a custom illuminator that provides illumination at the full width of the core for the layer by layer imaging. 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 data 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°.

We are also completing new illuminator specifically for the hyperspectral data that will observe at zero phase angle to eliminate any issues with topographic shading.

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.

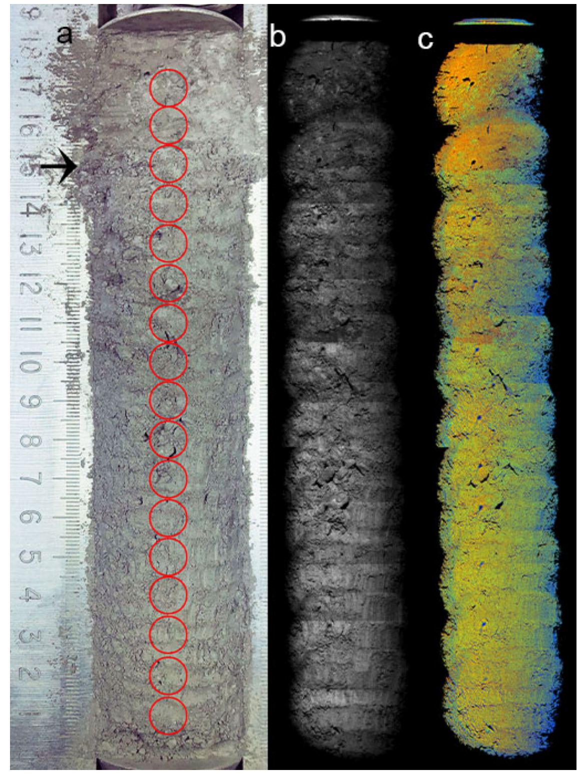

Fig. 1 Core 73002 images during the first dissection. (a) phone image, red circles are hyperspectral profile footprints, the scale is shown on the left, and the arrow indicates dissection progress. (b) 570 nm reflectance. (c) false colored image of the core, R=750 nm/415 nm, G=750 nm/950 nm, B=415 nm/750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

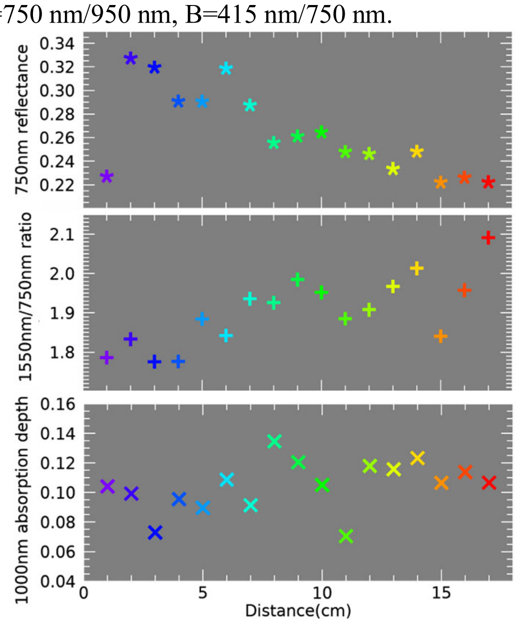

Fig.3 From top to bottom: variation of 750 nm reflectance, 1550 nm/750 nm ratio, and absorption depth at 1000 nm along the core.