CHARACTERIZATION OF LUNAR SOILS USING MICROSCOPIC HYPERSPECTRAL IMAGING. S.T. Crites*[1] and P.G. Lucey[1], [1]Hawaii Institute for Geophysics and Planetology, 1680 East West Road, POST 602, Honolulu, HI 96822 *scrites@hawaii.edu

Introduction: We have launched a project to characterize the mineralogy of a wide range of lunar soils through microscopic hyperspectral imaging of the samples. Our method allows rapid, direct characterization of the spectral properties and mineralogy of each individual grain in a sample. Pieters and Klima [1] showed the value of infrared microscopy for characterizing spectral properties of materials; following that lead, we have adapted infrared hyperspectral imaging systems developed for remote sensing under funding from the Planetary Instrument Definition and Development and Mars Instrument Development Program to enable microscopic spectral imaging at thermal, visible, and near infrared wavelengths.

This study will provide a database of mineralogy of a large number of Apollo soils that can be used as a calibration and validation tool for remote sensing mineralogy algorithms, and may also provide new insights into the geology of the Apollo landing sites.

Instruments and methods: We have implemented thermal emission spectroscopy using a microscopic imager based on a Sagnac interfometer equipped with a 320x256 element microbolometer array detector sensitive from 8 to 15 microns at 40 wavenumber resolution. It images a field of view of 8 millimeters at 30 micron spatial resolution and scans at a rate of about 1mm/second enabling relatively large areas to be scanned rapidly in either emission or reflectance. For emission spectroscopy, the samples are arrayed on a heated substrate in a single layer to prevent spectral interactions between grains. The setup also includes a reflectance attachment which allows for use on more temperature sensitive (non-lunar) samples. An advantage of the reflectance attachment is that it allows better differentiation of spectrally neutral grains from the background.

To date we have scanned with this system four individual soils (10084,97 12001,893, 14163,882, and 61221,175) prepared at different grain sizes (45-75 microns, 75-150 microns, 75-125 microns, and >75 mcrons) and either unwashed or washed to removed small grains with final data sizes of 256 x1000 pixels (8 by 40 mm).

Detection of specific minerals is based upon the correlation described in [3], which is a part of the Tetracorder algorithm. The algorithm measures the correlation between the test spectrum and library spectrum based on shape, and also returns a measure of the relative intensity of the test spectrum and library spectrum.

We also have implemented 0.9-2.5 micron capability using a microscopic imager based on an Offner spectrograph equipped with a cooled 320x256 HgCdTe array. Similar to the thermal infrared microscope, it images a field of view approximately 10 millimeters wide at 30 micron spatial resolution and a scan rate of about 1mm/second. Taking the cautions of [1] regarding low spectral contrast in near-IR spectroscopy, the samples are arrayed on a glass slide above a first surface mirror to allow dark field measurements that limit the signal to transmitted light. We have taken data on wet-seived samples of 12001,893, 14163,882, and 61221,175 in size fractions <25 microns, 25-45 microns, 45-90 microns, 90-150 microns, and >150 microns. Figure 1 shows an example dark field image of the >150 micron size fraction of soil 14163,882. The system uses a combination of infrared and halogen illuminators for strong signal across the full wavelength range. Figure 2 shows a spectrum of a lunar soil grain from sample 12001,893, with the 2 micron mafic signature visible. The lower signal near one micron has been improved by the addition of halogen illuminators.

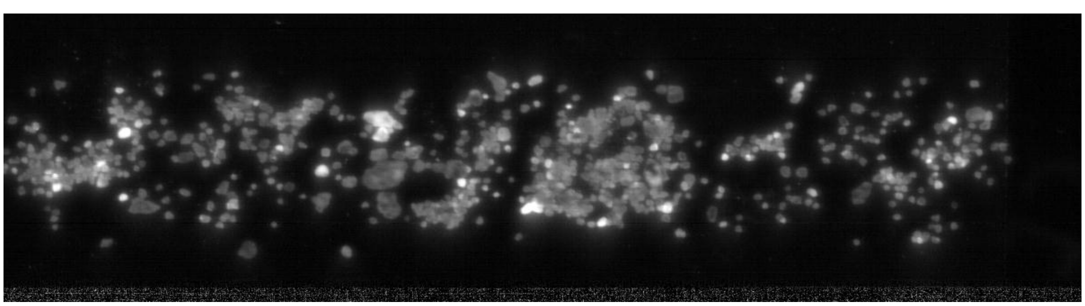

Figure 1. Near infrared dark field image of soil 14163,882 wet sieved to >150 microns.

In order to fully capture the 1-micron mafic bands, we have also implemented 500-900 nm capabilities to supplement the NIR measurements using a diffraction grating spectrograph equipped with a 1024x1024 CCD camera. This microscope images a field of view of 15 mm at approximately 30 micron spatial resolution and uses halogen bulbs for illumination. We have begun scanning mineral separates and have plans to collect lunar soil data concurrently with near infrared wavelengths in order to perform mineral identification and mafic mineral characterization using the full 0.5 to 2.5 micron range.

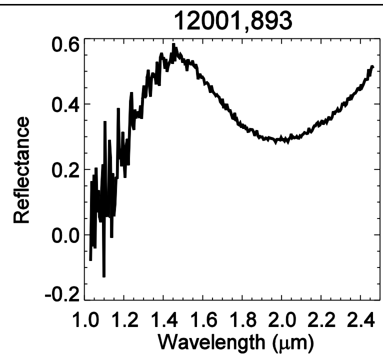

Figure 2. Near infrared spectrum of a mafic mineral in sample 12001,893 >150 micron size fraction.

Preliminary Results:

Mineral Detections. Using the thermal emission microscope, we identified minerals expected to be present in lunar soils, and using the thermal images created by the spectrometer, built spatial maps of the minerals in the soil. Grains of olivine, pyroxene, and feldspar were detected in all soils studied. Quartz was detected in small quantities in soils from Apollo 12 and Apollo 14, and apatite was detected in Apollo 14 soil. Figure 3 shows spectra of minerals detected in lunar soils compared with library spectra. The identification of minerals thought to be present in very small quantities demonstrates the potential of a grain-by-grain survey of lunar soils to locate and analyze rare components of the soils including rare minerals, meteoritic material, and material from distant areas of the Moon not visited by Apollo and Luna missions.

Conclusions: We have used a thermal infrared spectral microscope to successfully isolate minerals and agglutinates in lunar soil samples using emission, and are poised to begin mineral identification and spectral characterization of lunar soils in the VIS-NIR wavelength ranges. The characterization of lunar soil mineralogy at the individual grain level provides a valuable validation tool for remote sensing mineralogy algorithms. The ability of our methods to detect rare mineral components of lunar soils also demonstrates its value as a method for possibly isolating meteoritic or other exotic material in samples. Future work includes expansion and corroboration of the setup using a point Raman spectrometer and development of a robotic grain-picking system that will allow us to extract grains of interest. The ultimate goal is to do a comprehensive study of soils from each landing site without disturbing the samples, allowing selection and removal of grains of interest for further study.

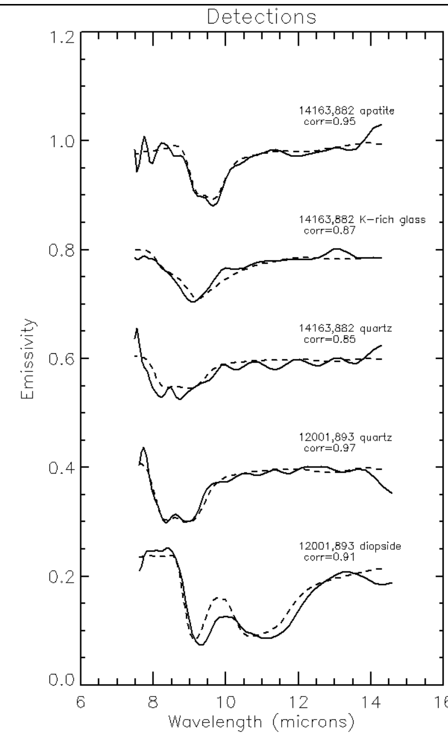

Figure 3: Spectra of selected minerals identified using thermal emission. *Corr* is a parameter describing the strength of the correlation with a reference spectrum.

References:

[1] Klima R.L. and Carle M. Pieters (2006), *JGR, 111*, E01005. [2] Spectral Library. V1.0. Arizona State Library, (Mars Space Flight Facility). Web. 31 Aug. 2010. [3] Clark, R.N., et al. (2006), *JGR, 108(E12)*, 5-1 to 5-44