**INFRARED REFLECTANCE SPECTRA OF SELECTED LUNAR SOILS AND MINERAL CONCENTRATES**; B. H. Betts and D. B. Nash, San Juan Capistrano Research Institute, 31872 Camino Capistrano, San Juan Capistrano, CA 92675, Email: betts@sji.org.

We have taken mid-infrared (2.2-25 μm, 4 $cm^{-1}$ resolution) FTIR reflectance spectra of soil samples from all six Apollo sites, and of mineral separates from an A-11, lunar basalt sample. Spectra of lunar soils show a general similarity between Apollo sites, but also show several significant differences between some sites, particularly in the transition spectral region (~4.5-6.5 μm) and in the shape and position of the Christiansen Frequency (reflectance minimum near 8 μm). A-16 soils have spectra that are very similar to spectra of breccia [1] from the same site, and significantly different from most soils at other sites (including those shown in [1]). Presumably this is due to soils in that highland region forming largely from anorthite-rich breccias. Spectra of mineral separates from A-11 basalt sample 10058 show that the spectral properties of the major mineral components (plagioclase, pyroxene, and ilmenite) can be clearly distinguished in those separates. We also find that particle size sorts of the original sample tend to isolate certain minerals and thus the spectra of larger particles look very different than those of smaller particles due to the difference in average composition. This work is part of a comprehensive study underway to catalog and understand the mid-infrared spectral properties of lunar materials for comparison with current and future infrared emission spectroscopy of the lunar surface.

**Experimental Method.** Biconical diffuse reflectance spectra were measured in our laboratory in dry $CO_2$-free air using an FTIR spectrometer covering 2.2-25 μm with a cooled HgCdTe detector. Sample reflectances were ratioed to the reflectances of a reference standard, gold-coated sandpaper [2]. Samples were placed in sample cups with their horizontal surfaces at the focal plane of the spectrometer. Mineral separates were formed by sorting grains by hand with tweezers under a microscope, and should be > 80% pure. Particle size fractions were obtained by sieving.

**Results.** Figure 1 shows sample spectra of soils from each of the Apollo landing sites. Note the general similarity of many of them. However, upon closer inspection there are significant differences, particularly in the strength and location of the combination overtone bands in the 4.5 to 6.5 μm region, the general slope in that region, and the location and shape of the Christiansen Frequency (minimum in reflectance near 8 μm). We are currently exploring the spectral variability of several soils from each Apollo site. A first look indicates that soil spectra are relatively uniform within a given site as would be expected; but more samples need to be run to confirm this. Obviously, this will have to be worked out to assess the variability between sites, but our current data indicates that there are real and consistent spectral differences between many of the sites. Comparison of our new soil spectra with the classifications of [1] shows that most of the conclusions of [1] about the general properties of lunar soil spectra remain valid. However, there is one new distinction: A-16 soils have spectra that are very similar to spectra of breccia [1] from the same site, and significantly different from most soils at other sites (including those shown in [1]). Presumably this is due to soils in that highland region forming largely from anorthite-rich breccias, whereas at other sites, soils are derived from a wider variety of rock types.

Figure 2 shows the spectra of mineral separates and particle size sorts for powdered material derived from an interior chip of lunar olivine basalt [3] rock sample 10058. The spectral properties of the three major individual minerals (in the original sample: plagioclase 45%, pyroxene 30%, and ilmenite 25% [3]) can be clearly distinguished by comparing the spectra. The particle size sorts were performed on the original (not mineral separates) sample. The spectrum of the finer particles (< 50 μm) in the bulk rock sample is dominated by a combination of the pyroxene and plagioclase, and the spectrum of the coarser sample (100-500 μm) is dominated by the ilmenite. The average grain sizes in the original sample were larger for the ilmenite [3], so crushing and sieving likely concentrated ilmenite in the coarser sample and plagioclase and pyroxene in the finer sample. We thank Jeff Mark and Kamran Vakili for laboratory and computer support. This work is supported by NASA PGG Grant NAGW 1350.

**REFERENCES:** (1) Nash, D. B., *Geophys. Res. Lett.*, *18*, 2145-2147, 1991. (2) Nash, D. B., *Appl. Optics*, *25*, 2427-2433, 1986. (3) Kramer, et al., Apollo 11 Lunar Sample Information Catalogue, JSC 12522, 1977.

INFRARED SPECTRA OF LUNAR SAMPLES: Betts B. H. and Nash D. B.

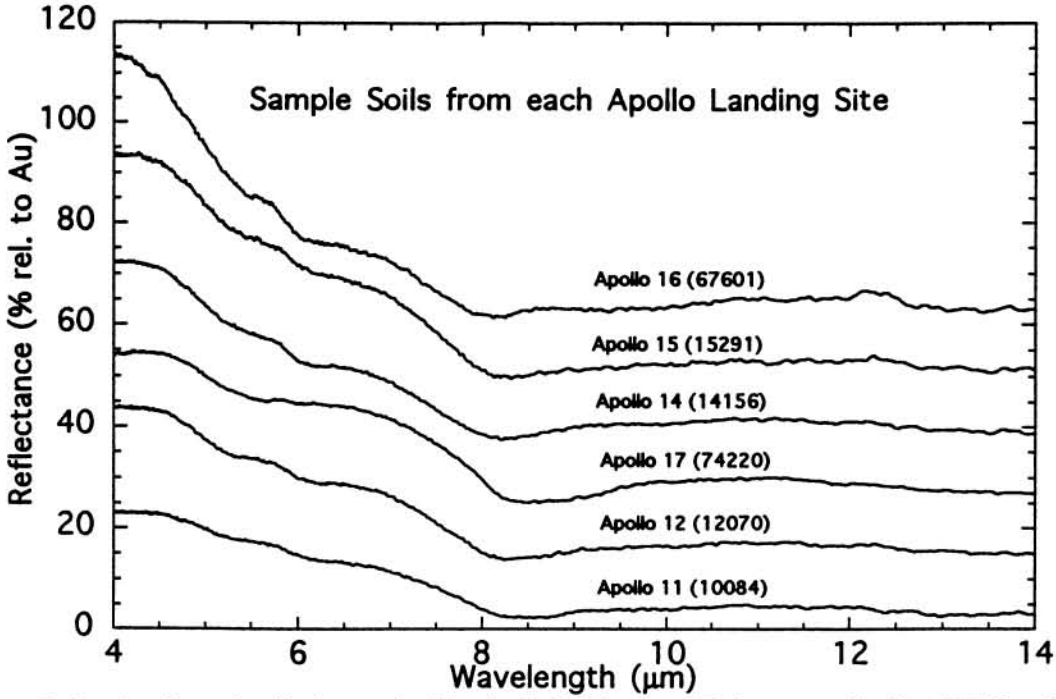


Figure 1: Spectra of sample soils from each of the Apollo landing sites. Each spectrum is offset 10% from the one below it. Note the variability in the weak combination and overtone bands in the 4.5 to 6.5 μm region, the variation in slopes in that region, the variation in location and shape of the Christiansen Frequency (CF) (minimum near 8 μm), and the lack of significant spectral contrast and variation in the Restrahlen Band region (longward of the CF).

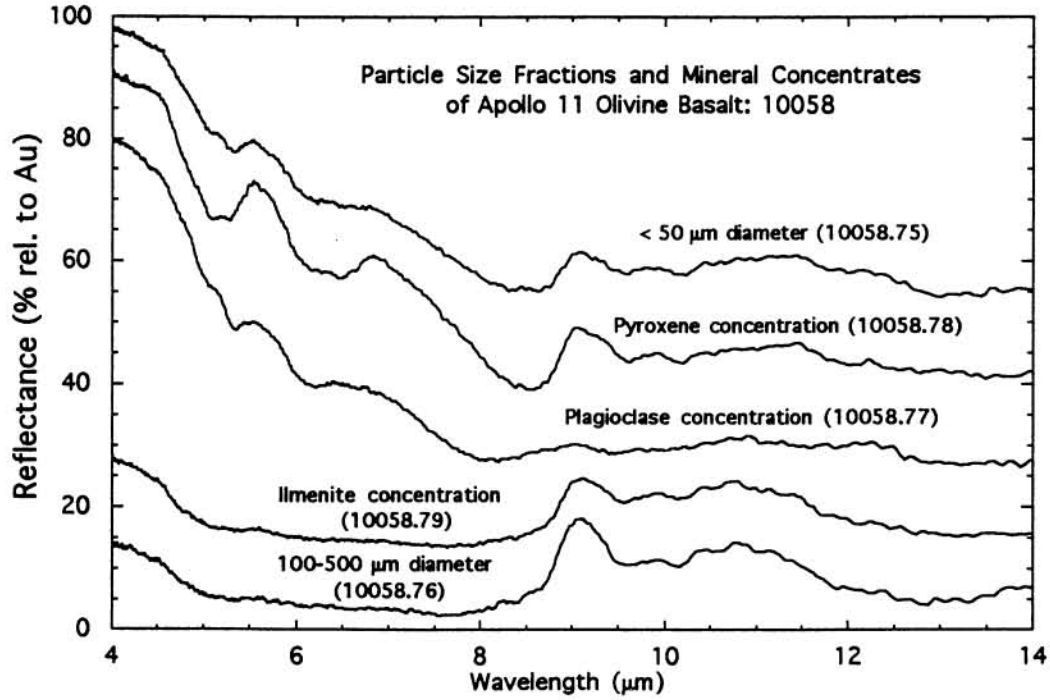


Figure 2: Spectra of mineral separates and particle size fractions of an interior chip of lunar basalt rock 10058. Each spectrum is offset 10% from the one below it. The samples include pyroxene concentrate, plagioclase concentrate, what was left over after separating out the pyroxene and plagioclase (mostly ilmenite). Note that the spectral properties of these individual minerals can be clearly distinguished by comparing spectra. The other two spectra shown are particle size fractions (< 50 μm diameter and 100-500 μm diameter) from powdering the original rock chip. Note that the finer particles appear to be dominantly a combination of the pyroxene and plagioclase, and that the coarser sample spectrum is dominated by the ilmenite.