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INFRARED REFLECTANCE SPECTRA (4-12 μm) OF LUNAR SAMPLES

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This work addresses infrared reflectance properties of lunar samples and is part of an ongoing study to assess the potential for using mid-IR thermal emission spectroscopy (TES) to map mineral composition on the Moon's surface from orbiting spacecraft. A recent evaluation of the TES technique (Nash et al, 1991) shows that despite some earlier worker's misgivings the TES technique holds great promise for providing useful mineralogical information about the Moon's surface.

Here are presented infrared reflectance spectra of a typical set of Apollo samples to illustrate spectral character in the mid-infrared (4-12 μm) of lunar materials and how it varies between three main forms: soil, breccia, and igneous rocks. Reflectance spectra, to a close approximation, are the inverse of emission spectra; thus for a given material the spectral reflectance (R) at any given wavelength is related to emission (E) by $1 - R = E$. We therefore can use reflectance spectra of lunar samples to predict how emission spectra of material on the lunar surface will appear to spectrometers on orbiting spacecraft or earthbased telescopes.

Spectra were measured in the lab in dry air using an FTIR spectrometer with cooled HgCdTe detector measuring reflectance from 2.3 to 25 μm relative to a gold-coated sandpaper reference material (for detail of the measurement system see Nash, 1986). Shown here is only the key portion (4-12 μm) of each spectrum relating to the principal spectral emission region for sunlit lunar materials and where the most diagnostic spectral features occur (Nash et al, 1991).

Spectra of seven typical lunar samples are shown in Figure 1. The zero level of each spectrum (except the bottom one) is offset upward in 10% increments for clarity. The compositional character of each sample (data from the Lunar Sample Catalogs) is shown in Table 1.

The spectra contain subtle but diagnostic features. The most prominent one is the minimum in reflectance (maximum in emission) occurring near 8 μm . This is the Christiansen Frequency (CF) feature, and its wavelength position is a strong indicator of composition (Conel, 1969; Salisbury and Walter, 1989), shifting to longer wavelength with increasing mafic composition. Next, weak absorption features in the 4.5 to 6.0 μm region, which are combination and overtone bands from molecular vibrations. And finally, the Reststrahlen Band (RB) region from 8.5 to 12.0 μm , where stretching vibration bands are diagnostic of composition but subdued by effects of fine particle size (Salisbury and Walter, 1989).

The spectra shown in Figure 1 illustrate several mid-IR spectral properties of lunar materials:

1. The breccias, in addition to having very high spectral contrast between 4 and 8 μm , show distinct spectral features indicating an Anorthite-rich plagioclase content. These features include the combination tone bands near 4.5, 5.6, and 6.2 μm ; the distinct CF minimum at 8.1 μm ; and the relatively flat sloping RB region from 8.5 to 12.0 μm (Nash and Salisbury, 1990).

2. The soils display medium spectral contrast between 4 and 8 μm ; the CF minimum shifts to longer wavelength with increasing soil maturity; the strength of combination tone bands near 5.2 and 6.2 μm are greater for soils with high crystalline content, lower for soils with high glass or agglutinate content.

3. Soils with high crystalline mineral content have a well-defined CF-minimum feature and combination tone bands at 5.2 μm (indicating pyroxene) and 6.2 μm (indicating plagioclase).

4. Igneous rock spectra show overall low spectral contrast, and a broad, poorly defined CF-minimum feature due to contributions from several mineral phases (plag, pyrox, oliv), but stronger reflectance in the RB region due to the absence of the effects of fine particle size.

These results suggest that in order to effectively utilize mid-IR thermal emission spectroscopy for lunar compositional mapping it is important that the origin of subtle features in spectra of soil and breccia materials be well understood, since it is these fine-particle-size forms of material that blanket most of the lunar surface, and that will dominate the character of any spectra measured from lunar orbit or beyond. Such work including laboratory measurements and theoretical modeling needs to be carried out.

IR REFLECTANCE OF LUNAR SAMPLES: Nash, D.B.

References: Conel, J. E. (1969); Infrared emissivities of silicates: Experimental results and a cloudy atmosphere model of spectral emission from condensed particulate mediums; JGR 74, 1614-1634. Nash, D.B. (1986); Mid-infrared reflectance spectra (2.3-22 μm) of sulfur, gold, KBr, MgO, and Halon; Appl. Opt. 25, 2427-2433. Nash, D.B. and J. Salisbury (1990); Infrared reflectance spectra of plagioclase feldspars; LPSC XXI, 845-846. Nash, D.B., J. Conel, P. Christensen, P. Lucey, and J. Salisbury (1991); Evaluation of thermal emission spectroscopy for compositional mapping of the Moon's surface from a polar-orbiting spacecraft; (submitted to JGR). Salisbury, J.W. and L.S. Walter (1989); Thermal infrared (2.5-13.5 μm) spectroscopic remote sensing of igneous rock types on particulate planetary surfaces; JGR 94, 9192-9202.

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		Plag	Pyrox	Oliv	Ilmen	spinel, troil., or crist. Fe	Agglut. Glass	lithic	notes
(A) Breccia	67455	80-90	10-20	?	?		~10?		[1]
(B) Breccia	67031	~90?	~10?	trace	-----scarce-----		trace		[2]
(C) Soil	15421	1	2				97		[3]
(D) Soil	15531	8?	30?	6?	-----?-----		A-23 G-5	35?	[4]
(E) Soil	10084	2	-----4-----		-----1-----		65	26	[5]
(F) Rock	15557	35	50	10-15	-----5-----				[6]
(G) Rock	10020	30	50	4	16				[7]

- Notes: [1] Matrix has black/grey material.
 [2] Has clasts of gabbro/norite; ferran anorthosite.
 [3] Very immature soil; green glass.
 [4] Immature soil; lithics 21%, breccia 6%, indeterminate 8%.
 [5] Mature soil; mare-basalt lithics 24%, highland lithics 2%.
 [6] Very friable, medium grained; olivine basalt.
 [7] Olivine basalt.

Figure 1. Reflectance spectra in dried air at room temperature. Rock spectra are for clean surface of solid chips, all others are for particulate material as it was returned from the Moon, placed loosely in analysis cups, and lightly compressed with glass slide to make a smooth flat surface.

