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MID-INFRARED EMISSION SPECTRUM OF APOLLO 14 SOIL: SIGNIFICANCE FOR COMPOSITIONAL REMOTE SENSING; L. M. Logan, G. R. Hunt, S. R. Balsamo, and J. W. Salisbury, Terrestrial Sciences Laboratory, Air Force Cambridge Research Laboratories, L. G. Hanscom Field, Bedford, Mass., 01730.

In principle, a mid-infrared emission spectrum of a planetary surface offers information diagnostic of bulk mineralogical composition, or rock type. This is because features which occur in mid-infrared spectra are caused by vibrations within the basic repeating units of the material. Thus, the number and location of the bands depends directly upon the molecular structure and, hence, on mineralogical composition.

There has, however, been serious disagreement concerning the amount of such information available in lunar infrared emission. Early laboratory work showed that the molecular vibration bands (reststrahlen bands) of silicate minerals become more difficult to detect as the particle size of the minerals becomes small (Lyon, NASA Tech. Note TND-1871, 1963). Because the lunar surface layer has long been known to be composed primarily of fine particulate material, it has been generally assumed that it radiated essentially as a black body in the mid-infrared.

Yet, early observations of lunar emission did detect differences in spectral behavior from place to place on the surface (Hunt & Salisbury, Science, 146, 641, 1964), and one observer determined that lunar emission departed significantly from black body behavior (Murcray, J.G.R., 70, 4959, 1965). On the other hand, later observations indicated that, although the emissivity of some areas differed from that of their surroundings, the emissivity of most areas did not (Goetz, J.G.R., 73, 1455, 1968). The most recent measurements, which have the advantage of being made with a balloon-borne telescope above most of the infrared-absorbing constituents of the atmosphere, showed that the moon did, indeed, depart from black body behavior (Murcray et al, J.G.R., 75, 2662, 1970). They also showed that the spectra display a pronounced peak near 8.0 microns, the position of which varies from place to place on the surface (see Figure 1).

Although the presence of an emissivity peak was explained by the work of Conel (J.G.R., 74, 1614, 1969) as a spectral feature associated with the principal Christiansen frequency, this work predicted a 2 or 3% feature at most, rather than the 10 to 20% effect shown in Figure 1. Logan and Hunt (Science, 169, 865, 1970) have recently shown that this large departure from black body behavior is due to the thermal environment of the lunar surface. That is, heating of the surface by illumination in vacuum, while it radiates to cold space, will result in a very steep thermal gradient near its surface.

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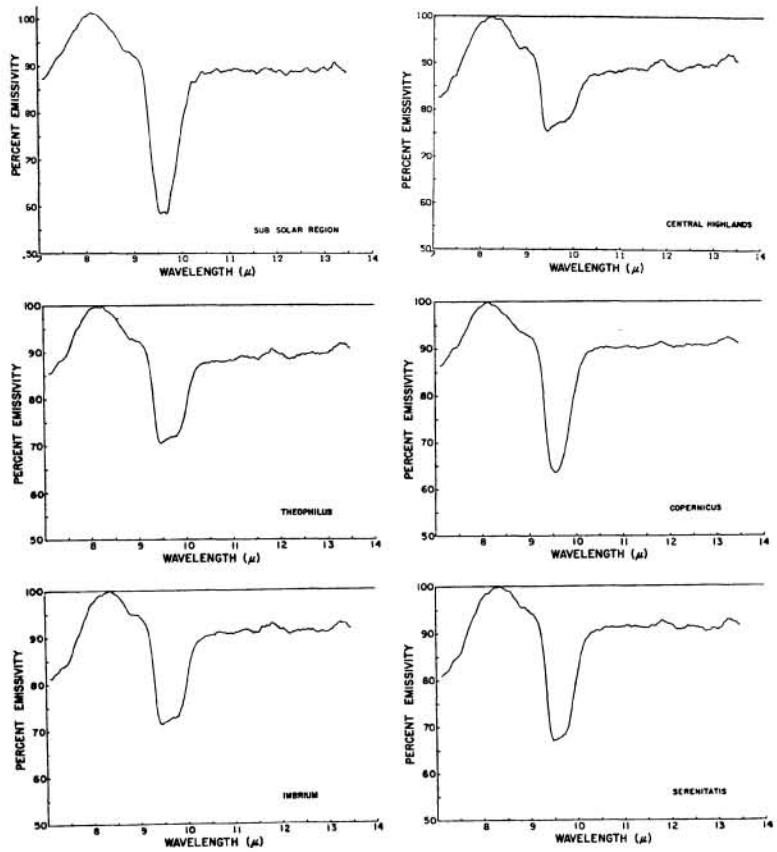

Figure 1. Spectral emissivity of six different lunar regions obtained with a balloon-borne telescope. The strong band near 9.6 microns is due to absorption by residual ozone in the earth's atmosphere. (From Murcray et al, J.G.R., 75, 2662, 1970).

Such a thermal gradient is accompanied by a strong emissivity peak.

Laboratory study of terrestrial rocks in a simulated lunar environment has demonstrated that the position of the emissivity peak, together with the average departure of a spectrum from black body behavior, are two parameters that serve to clearly distinguish among different rock types (Logan et al, in preparation). To apply the technique to the moon, however, it must be demonstrated that lunar rocks follow the same rules of peak location and average emissivity as do terrestrial rocks.

To this end the emission spectrum of a sample of Apollo 14 soil (14259) has been obtained in a simulated lunar environment (see Figure 2). We find that the peak location and average emissivity of this sample are typical of silica-poor basaltic rocks, which is entirely consistent with the composition of the soil. The departure from black body behavior displayed by the Apollo

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14 soil spectrum is generally not so great as that determined by the balloon-borne telescope system for some areas on the moon. This may be due to a true difference in emissivity for these areas, or to inadequate calibration of the balloon spectrometer. The position of the Apollo 14 soil emission peak (8.24 microns) is identical with that previously determined for the Central Highlands with the balloon system. That the two peaks are identical is reasonable, if the regolith in the Central Highlands and the debris ejected from the Imbrian basin to form the Frau Mauro formation are both derived from the lunar crust. It is noteworthy that an emissivity peak at this long a wavelength implies that the Central Highlands regolith cannot be derived from "anorthosite", if by that term is meant a rock composed almost entirely of calcic plagioclase. On the contrary, the regolith must contain abundant pyroxene and/or olivine, as does the Apollo 14 soil.

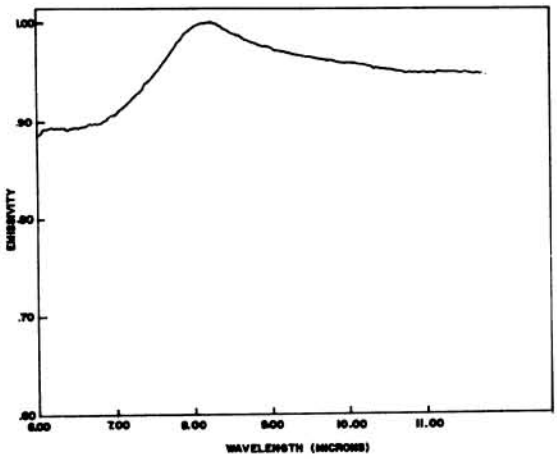

Figure 2. Emission spectrum of Apollo 14 soil obtained in a simulated lunar environment.

We conclude, therefore, that 1) the moon deviates significantly from black body behavior in its infrared emission; 2) spectra already available of different areas on the lunar surface indicate that the Central Highlands material, although less basic than the maria materials, is gabbroic rather than anorthositic; and 3) mid-infrared spectroscopy is a valid lunar remote sensing tool, which could be most useful in indirect exploration.