MID INFRARED SPECTRA OF LUNAR AND ANALOG SOILS

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The potential for compositional analysis of the lunar surface by infrared spectroscopy has long been recognized. Difficulties in the interpretation of laboratory data led to the development of a new theory(1) of the emittance spectra of mineral powders which has resulted in excellent agreement between experimental measurements and theoretical simulations.(2) This effort utilized a small number of model minerals as little data on the optical constants of minerals in the infrared region was available.

In order to ascertain the degree of diagnostic information that would be available in the actual lunar case, we then undertook a program of measurements of terrestrial analogs of lunar soils.(3) This program included emittance measurements using our Michelson interferometer spectrometer and theoretical predictions based on the already developed computer model, using the optical constants of the relevant mineral species. In most cases these optical constants had to be developed during the work due to the lack previously mentioned. We obtained optical constants for dunite, bytownite, augite, ilmenite and a mare glass analog during this work. Data were obtained by reflectance measurements on homogeneous samples and reduced by a computer program that fits the data to Lorentz line parameters.(4) Using these optical constants, theoretical simulations were made and compared with the experimental data. The results indicated that for relatively coarse particles, theory and experiment compare very well, but for fine particles the fit is rendered unsatisfactory in regions of high particle transparency owing to difficulties in obtaining appropriate values of the absorption index by our method. We believe this defect can be remedied by measuring transmittance spectra of thin sections of the relevant minerals in such transparent regions.

Owing to early reports(5, 6) of the very low contrast inherent in the lunar spectrum, and recognition that contrast reduction would occur because of the high glass content, the presence of many very small metallic particles in the lunar agglutinates, and the fine particle nature of the lunar soils, we began a study of the lunar soils themselves to establish the degree to which experimental measurements made from orbit could be expected to derive planetary mineralogy.

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Our first measurements were made on sample 10084. This sample, when measured under an atmosphere of dry nitrogen, shows an average emittance value of about 0.9 between 300 and 1200 wave numbers, which is the region of the diagnostic features for silicate minerals. Three bands can readily be seen in the silicon oxygen stretching and silicon oxygen bending portions of this spectrum. These bands have very low contrast (less than .02 emittance units) but are readily measured by our apparatus even in observation times of less than 20 minutes. Bands are centered at 1100 cm^{-1}, 850 cm^{-1}, and 500 cm^{-1} with the high frequency band being very weak. Beyond 1170 cm^{-1} a steady emittance decrease to about 1400 cm^{-1}, which is the highest frequency in our data, is observed. This is due to the increasing transparency of the individual silicate particles beyond the "Christiansen region." The presence of the three bands indicated above confirms the predictions we made some ten years ago(7) that diagnostic information would necessarily be present even in the spectra of fine powders, and the low contrast shows why there is difficulty in observing emittance features through the earth's atmosphere. The 1170 cm^{-1} "Christiansen frequency" is in accord with an ultramafic composition(8) for the Apollo 11 soil. In addition, a comparison of the data from sample 10084 with our analog results suggests several preliminary conclusions. First, the spectrum is similar to our analog mixtures in position of features but of lower contrast. The reduced contrast may be explained by the presence of agglutinates. Our analog work indicated that a band near 830 cm^{-1} arises from fine particle feldspar while the 1100 cm^{-1} band comes from pyroxenes.

We then made measurements on sample 67711. In this case the data are quite similar to our analog results for feldspar. The average emittance of this spectrum is similar to that for 10084, but the contrast is about five times as great. This is to be expected from such an immature soil owing to the lack of substantial agglutinates. Both the glass and small metallic particles present in agglutinates are expected to reduce the spectral contrast.

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