

Mid-Infrared Reflectance Spectra for Planetary Surface Study. G. P. Meeker, G. R. Rossman and A. L. Albee, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.

It is the purpose of this report to evaluate the information which could be obtained by using mid-infrared (2.5 - 40 μm) reflectance spectra on board a lander spacecraft, to examine rocks, minerals, soils and weathering products on a planetary surface. Samples would be illuminated from an onboard incandescent source and the spectrometer would operate similar to laboratory spectrophotometers. Samples would consist of rocks, aggregates, and powders and would be examined with no sample preparation other than the need to position them in the optical path.

Experimental. Radiation from the sample beam of double beam infrared spectrophotometer is reflected onto a sample by a microreflectance apparatus, collected, ratioed against a reference beam containing a standard mirror reflector and attenuators, and presented in a linear absorbance mode. Samples consisted of mineral and rock powders of various particle sizes, and whole rock specimens run "as-is" on both fresh and weathered surfaces.

Results. Reflection spectra provide much of the same information which can be obtained from transmission spectra and can generally provide significantly better quality data than emission spectra (Figure 1). Chemical groups such as carbonate and silicate can be readily distinguished, the mineralogical family of most silicates, alumino-silicates, carbonates, sulfates, etc. can be ascertained, and with single phase samples, the mineral species can frequently be identified. Absorbed and structural water can be detected, several individual phases in rocks can often be identified and the general rock type can be determined from the overall appearance of the reflectance pattern. The silica content of rocks can be estimated from the reflectance spectra. Spectra of freshly broken surfaces show a shift of the vibrational bands of the tetrahedral framework in the 900 to 1200 cm^{-1} region to lower wavenumbers as rock compositions vary from felsic to mafic (Figure 2). Quantitatively more useful is the correlation between SiO_2 concentration and the position of the principal Christiansen frequency (Figure 3). For about 90% of the rocks examined, the silica content could be determined to within 10% for mafic rocks and to within 15% for felsic rocks from the position of the principal Christiansen frequency alone.

Particle Size. The effects of particle size can complicate the nature of the reflection spectrum. When the particles are large, a major component of the reflected radiation is the result of specular (surface) reflection. When the particle size is small compared to the wavelength, diffuse (internal) reflection dominates. For particle size comparable to the wavelength (e.g. < 38 μm in Figure 4) spectra comprised of both specular and diffuse components are obtained. Most crystalline rocks examined produced spectra with the specular component dominant in the 200 - 1400 cm^{-1} region. The quality of spectra obtained from fine powders can be improved through compaction. Figure 5 illustrates how the spectrum of andesite powder becomes more specular upon compaction.

Water. Specular reflection from water and hydroxide ion stretching modes is observed in the cases of single-crystal hydrated minerals and polycrystalline, nearly monomineralic rocks such as gypsum. Usually, the water absorption is observed as a broad, diffuse reflection in the $3000 - 3700 \text{ cm}^{-1}$ region. Hydroxide ion features from clays and micas are usually observed in the $3500 - 3700 \text{ cm}^{-1}$ region as diffuse reflections of comparatively narrow line width. Changes in the desorption and sorption of water in response to heat and vacuum are illustrated in Figure 6 for a $74 - 43 \mu\text{m}$ powdered andesite initially of 5 % surface water. The spectra readily detect the loss of 3 % H_2O on heating. Weathering rinds and superficial coatings can modify or obscure the reflection properties of the underlying rock. The effects of weathering on the reflectance pattern of most rocks include the modification of the intensity of the spectral bands, the addition of contributions from the weathering products themselves, and an increase in the amount of diffuse water reflectance (Figure 7). In the extreme case of a coating of desert varnish, the reflectance spectra demonstrate the progression from fresh rhyolite to a dominantly illite-montmorillonite coating (Figure 7).

Conclusion. Reflectance spectra in the mid-infrared region are capable of providing information about mineralogy and petrology with a minimum of sample preparation and would have value both for study of materials on a planetary surface and for selection of samples for sample return. Because the spectrometer would provide its own source, cryogenic detectors would not be required, and spectra could be obtained to wavelengths as long as $40 \mu\text{m}$.

Reference. Conel, J. E. (1969) Infrared emissivities of silicates: experimental results and a cloudy atmosphere model of spectral emission from condensed particulate mediums. *J. Geophys. Research*, 74, 1614-1634.

- Figure 1. Comparison of reflectance and emittance (Conel, 1969) spectra of $38 \mu\text{m}$ quartz particles and a KBr absorption spectra. Spectra are presented such that maximum signal at the detector is at the lower portion of the trace.
- Figure 2. Reflectance spectra of representative rocks ranging from felsic to ultramafic in composition.
- Figure 3. Variation of the principal Christiansen frequency peak (indicated by the arrow by the granite spectrum in Fig. 2) as a function of SiO_2 content for 42 different rocks.
- Figure 4. Variation of spectral pattern of andesite powder with particle size.
- Figure 5. Reflectance spectra of andesite powder showing the increase reflectance in the $800 - 1200 \text{ cm}^{-1}$ region produced by compaction of the surface.
- Figure 6. Changes in the intensity of the O-H region of powdered andesite in response to heat and vacuum.
- Figure 7. Reflection spectra of fresh and weathered surfaces.

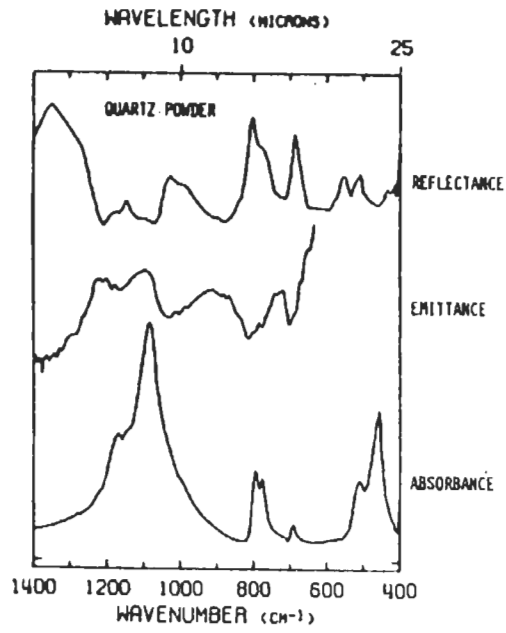


FIGURE 1

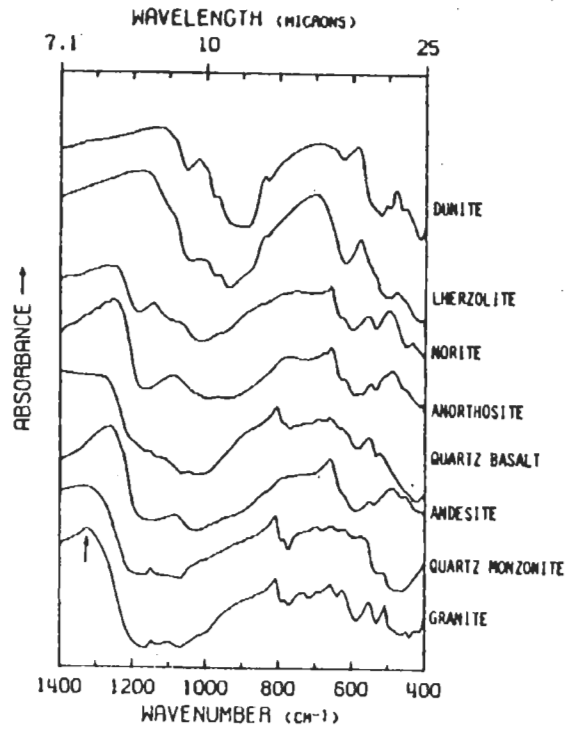


FIGURE 2

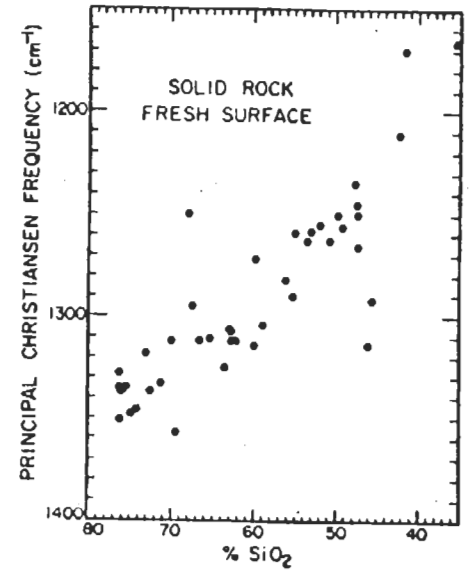


FIGURE 3

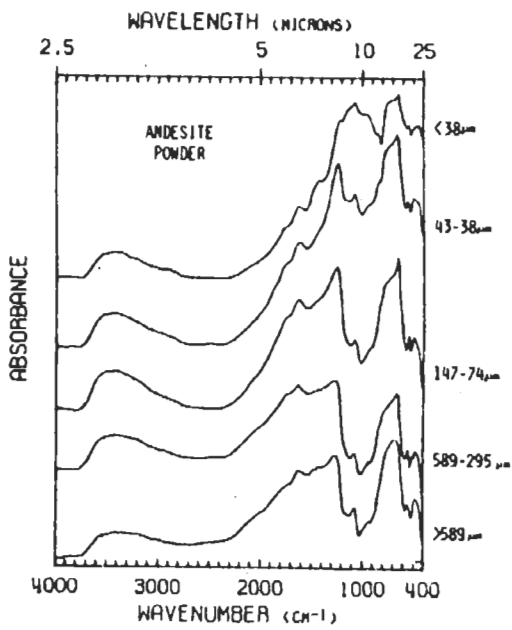


FIGURE 4

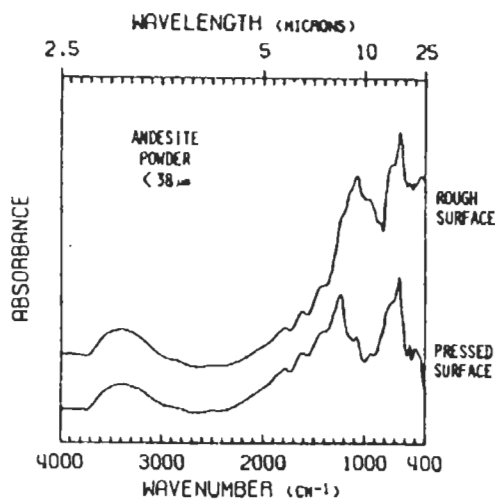


FIGURE 5

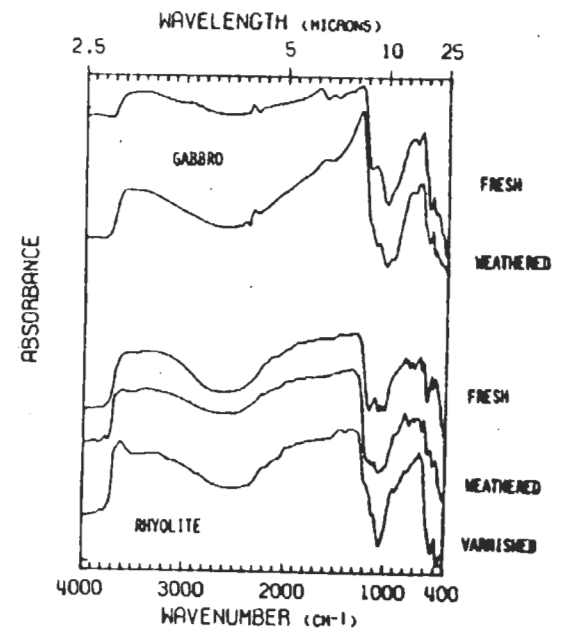
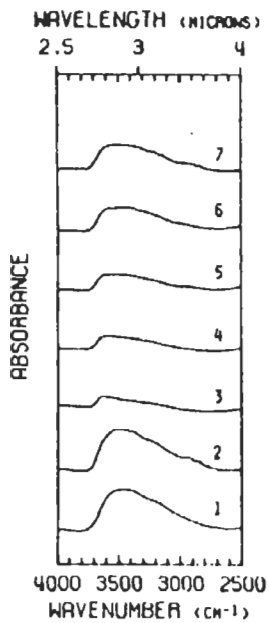


FIGURE 7



WATER CONTENT IN POWDERED ANDESITE	
PROCEDURE	EFFECT ON WATER BANDS
1 INITIAL SAMPLE	
2 SAMPLE HEATED TO 120 °C FOR 24 HRS. IN EVACUATED CONTAINER	NO OBSERVABLE CHANGE
3 SAMPLE HEATED TO 420 °C FOR 24 HRS.	INTENSITY GREATLY REDUCED
4 SAMPLE LEFT IN 38% HUMIDITY AT ROOM TEMPERATURE FOR 24 HRS.	LITTLE OR NO INCREASE IN INTENSITY
5 SAMPLE COVERED WITH WATER AND DRIED UNDER AN INFRARED LAMP AT 46 °C	SLIGHT INCREASE IN INTENSITY
6 SAMPLE COVERED WITH WATER FOR 7 DAYS AND DRIED AS ABOVE	SIGNIFICANT INCREASE IN INTENSITY
7 SAMPLE HEATED TO 120 °C FOR 24 HRS. IN EVACUATED CONTAINER	NO OBSERVABLE CHANGE

FIGURE 6