THERMAL-INFRARED SPECTRAL OBSERVATIONS OF GEOLOGIC MATERIALS IN EMISSION

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Thermal-infrared spectroscopy provides a powerful tool for determining the composition of planetary surface materials. Virtually all silicates, carbonates, sulfates, phosphates, oxides, and hydroxides have thermal-infrared spectral features associated with the fundamental vibrational motions of the major ionic groups in the crystal structure. The vibrational frequency of these motions, and therefore the wavelength of energy absorbed, varies with both the ionic composition and crystal lattice structure. This variability provides a direct means of identifying the composition of many geologic materials, and for interpreting the crystal structure, and therefore the mineralogy of these materials. Because rocks are composed of mixtures of mineral phases, this technique also permits the petrology of the rocks and soils exposed at the surface to be determined.

The Thermal Emission Spectrometer (TES) instrument is a thermal-infrared spectrometer that is currently being developed for use on the Mars Observer mission. To support this investigation, a series of laboratory measurements of candidate martian materials has been initiated. These observations are intended to characterize the spectral properties of geologic materials in emission, and to study a variety of processes and surface modifications that may influence or alter the spectra of primary rock materials.

Pioneering studies of the thermal-infrared absorption characteristics of minerals were have been performed (Lyon, 1962, 1964; Farmer, 1974; Hunt and Salisbury, 1974, 1975, 1976). The vast majority of these studies have measured the spectral properties of materials in either transmission or reflection, whereas remote sensing observations of planetary surfaces measure the amount of energy emitted. In theory, reflectance measurements can be related to emission measurement assuming Kirchoff's law, where the fraction of emitted (ε) and reflected (R) energy are related by:

$$\varepsilon=1-R$$

However, this relationship is only strictly valid for measurements of the total hemispherical reflection and emission from a mat surface, rather that the reflection from a polished surface as is often measured (Hunt and Vincent, 1968).

In the studies reported here, we have acquired thermal-infrared spectra of materials in emission. These observations were acquired using the prototype TES brassboard spectrometer. This instrument is a Fourier transform interferometer, which covers the spectral range from 7 to 18 µm at a spectral resolution of 5.5 cm^{-1} (0.055 µm at 10 µm wavelength). This resolution is approximately a factor of two better than will be achieved with the Mars Observer instrument, allowing the detailed spectral properties to be investigated and interpreted. The instrument is controlled, the spectra are acquired, and the data are processed and analyzed using an IBM PC-XT microcomputer.

To acquire a spectra the sample is heated in a temperature-controlled oven for 4-6 hours to achieve a uniform temperature throughout the sample. At present, only solid rock samples have been investigated, in order to minimize the effects of temperature gradients within the samples, which are known to cause uncertainties in the observed spectral properties (Logan and Hunt, 1970; Logan et al., 1975). The samples are removed from the oven and their spectra acquired within 20 sec to again minimize the effects of temperature gradients. Spectra are also acquired of a very accurately controlled blackbody reference surface, and of liquid nitrogen to determine the instrument response and background emission respectively. This suite of observations permits absolute determination of the emissivity of the sample, provided that the kinetic temperature of the sample is known. Because of the difficulty in measuring and interpreting the surface temperature of the sample, the temperature is determined by fitting a blackbody curve to the observed spectra. This technique is illustrated in Figure 1. The Michelson mirror position is accurately determined using a visible light interferometer to count the fringe patterns of a neon light source. This standard technique permits an absolute wavelength determination to be made that is accurate and repeatable to approximately 0.01 µm at 10 µm. Double-side interferograms are acquired to permit phase offsets and non-linearities in the beamsplitter and interferometer to be removed.

Figure 1a shows the initial spectrum acquired for a quartz crystal, together with the best-fit blackbody curve used to estimate the sample temperature. Figure 1b show the same data after the observed spectrum has been divided by the blackbody to determine the emissivity of the crystal. Figure 2 shows a similar set of spectra taken of a basalt sample returned from the Cima volcanic field in the Mojave desert, California. This sample was acquired from a flow surface contained within a region imaged by the Thermal Infrared Mapping Spectrometer (TIMS) airborne instrument (see Kahle and Goetz, 1983). Figure 3 gives the emissivity of a carbonate sample acquired from within the same TIMS scene.

These spectra confirm that thermal emission spectra contain the same absorption features as have been previously observed in transmission and reflection spectra, and demonstrate the successful utilization of the TES prototype instrument to obtain relevant spectra for analysis of rock and mineral composition.

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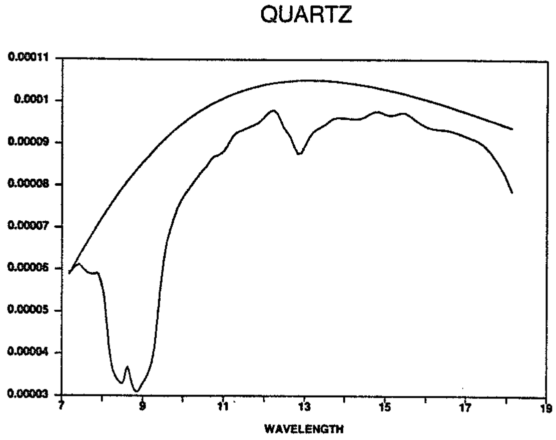

Fig. 1a

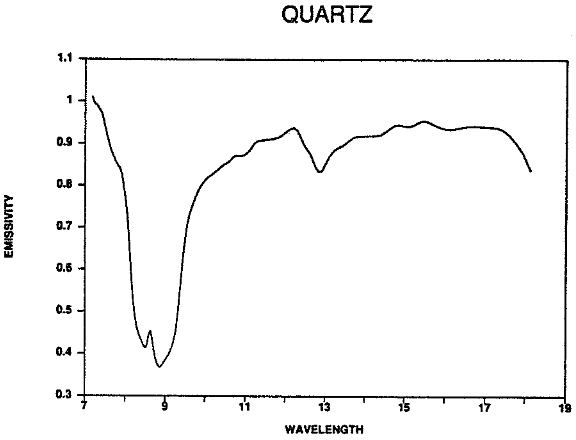

Fig. 1b

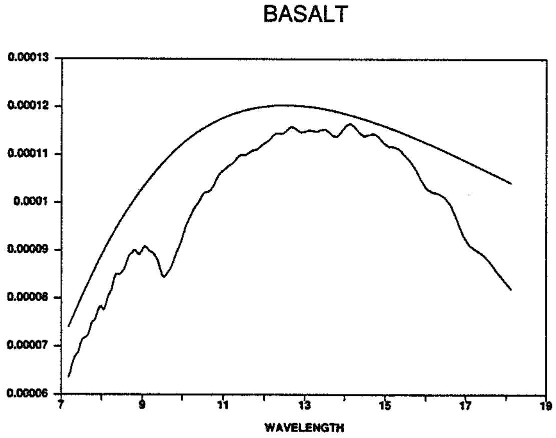

Fig. 2a

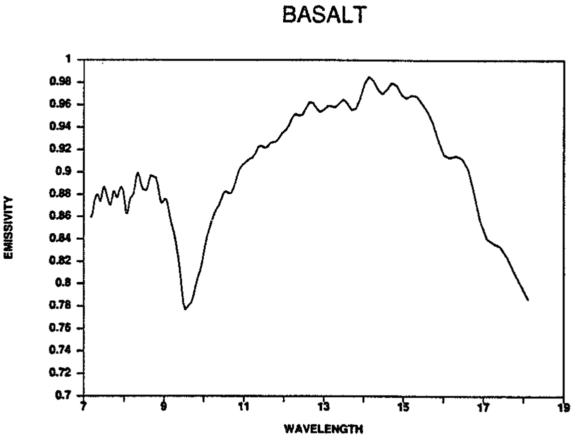

Fig.2b

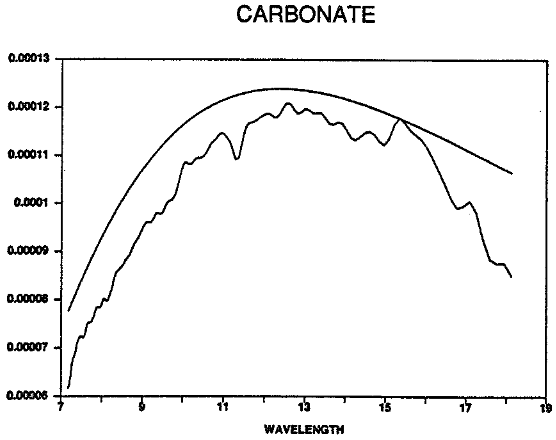

Fig. 3a

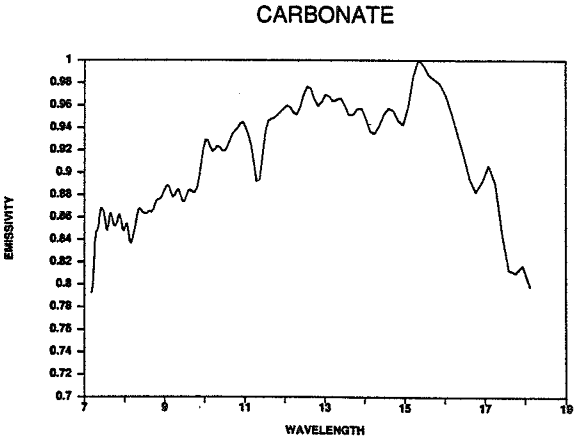

Fig. 3b