

N86-13802

**Thermal Infrared Geologic Remote Sensing Research
at the Jet Propulsion Laboratory**

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January 29, 1985

JUSTIFICATION

Remotely sensed thermal infrared spectral data have great potential to improve rock type discrimination if the factors that control thermal infrared spectral reflection and emission can be better understood. Improved rock type discrimination in turn leads to better and more efficient geologic mapping which is carried out in the exploration, assessment and documentation of mineral resources and geologic hazards. Geologic maps also contribute significantly to the understanding of the natural history of the earth and neighboring planetary bodies.

OBJECTIVES

The particular goal is to study the spectral emission and reflection behavior of rock materials (rocks, rock weathering products and soils) as a function of earth-like environment and occurrence. Some of the important environmental variables that influence the earth's near surface thermal regime and hence its thermal emission are sky temperature, sky field of view, microclimatology, time of day and season of the year. In addition, chemical and physical factors, mineralogy, particle size, surface roughness, presence of desert varnish and rock weathering, play a role.

APPROACH

The approach involves both field and laboratory investigations. The field work is divided between airborne and ground based studies. Remotely sensed mid-infrared spectral data of the earth can be acquired by the airborne Thermal Infrared Multispectral Scanner (TIMS) (Kahle and Goetz 1983; Palluconi and Meeks, 1985). TIMS measures normal spectral radiance of the earth's surface. It has six channels from 8 to 12 μm and is flown in a NASA Lear Jet. (Within this range the transmission of the earth's atmosphere is good and intense absorption features are present in surface silicate materials.) Computer image enhancement research is a significant part of TIMS investigations.

The ground based field work is carried out with the Portable Field Emission Spectrometer (PFES) which is used to make normal spectral radiance measurements from 3 to 14 μm . This JPL-built instrument is mounted and carried by backpack. The PFES has a spectral resolution of approximately .2 μm which makes it an important tool that can be used in interpreting TIMS data.

However, some scientific questions in this subject require the kind of experimental control that can only be provided in the laboratory. For example, the influence of earth-like near surface thermal gradients, desert varnish, rock weathering, particle size and surface roughness on the spectral emission of rock materials needs to be understood and can only be studied in

an environment that is free from variations in sky temperature, microclimatology, and sky field of view and unaffected by the season of the year or the time of day.

Therefore, we are developing the capability to measure in the laboratory the normal spectral radiance of rock materials at ambient temperatures ($\sim 20^\circ\text{C}$). This involves the careful design and construction of a sample accessory, called the emissivity cold box, for a commercial Fourier Transform infrared spectrometer that allows control and stabilization of sample temperature while shielding it from background radiation, (Brown and Young, 1975; Aronson and Enslie, 1973; Logan and Hunt, 1970; Conel, 1969; Low and Coleman, 1966; Lyon, 1965). A schematic diagram of the sample accessory is shown in Figure 1.

Liquid nitrogen will be used to control the temperature of the walls of the cold box and dry gaseous nitrogen will control the sample temperature. The temperature of the gaseous nitrogen will be controlled by a liquid bath. A separate liquid bath will be used to control the temperature of gaseous nitrogen that purges the spectrometer's optic bench.

The cold box will take the place of the spectrometer's source mirror during the measurement of sample radiance. Modifications to the spectrometer that allow this are already complete. Furthermore, the spectrometer's standard pyroelectric detector has been replaced by a more sensitive liquid nitrogen cooled mercury-cadmium-telluride detector.

With this configuration the sample radiance at the detector can be characterized as

$$L(\lambda, T_1) = K(\lambda) [\varepsilon(\lambda) W(\lambda, T_1) + R(\lambda) + S(\lambda)] \quad (1)$$

where $L(\lambda, T_1)$ = radiation at detector

T_1 = temperature of sample

$K(\lambda)$ = instrument response function

$\varepsilon(\lambda)$ = emissivity of sample

$W(\lambda, T_1)$ = black body radiation at temperature T_1

$R(\lambda)$ = radiation reflected by sample

$S(\lambda)$ = background radiation

then by making these additional measurements,

$$L(\lambda, T_2) = K(\lambda) [\varepsilon(\lambda) W(\lambda, T_2) + R(\lambda) + S(\lambda)] \quad (2)$$

$$B(\lambda, T_1) = K(\lambda) [W(\lambda, T_1) + S(\lambda)] \quad (3)$$

$$B(\lambda, T_{\text{LN}2}) = K(\lambda) S(\lambda) \quad (4)$$

where T_2 = temperature of sample different from T_1
 T_{LN2} = temperature of liquid nitrogen
 $B(\lambda, T_1)$ = radiation at detector from blackbody at
temperature T_1

the sample emissivity can be calculated as follows.

$$\epsilon(\lambda) = \frac{L(\lambda, T_1) - L(\lambda, T_2)}{B(\lambda, T_1) - B(\lambda, T_{LN2})} \cdot \frac{W(\lambda, T_1)}{W(\lambda, T_1) - W(\lambda, T_2)} \quad (5)$$

All values in equation 5 are either measured or calculated from Planck's Law once the temperature of the sample is known.

Two techniques will be used to determine the sample's temperature. First, thermocouples will be located on or near the top and bottom surfaces of the sample. Second, the surface temperature will be computed from the radiance at the sample's Christiansen frequency (Conel, 1969; Aronson et al., 1969).

RESULTS

An example of TIMS data from Death Valley, California is given in Figure 2. These images show variation in emittance across part of the Panamint Mountains, valley floor and part of the Funeral Mountains. The light areas indicate high emittance and the dark low emittance. The values upon which the images are based were calculated from Planck's Law and TIMS data. These data have been used to make lithologic maps of bedrock and alluvial fans in Death Valley (Kahle and Goetz, 1983; Gillespie, Kahle and Palluconi, 1984).

Figure 3 shows PFES data from Death Valley. The silicate absorption doublet from 8 to 10 μm can be clearly seen in the quartzite spectra. This feature is only hinted at in the spectra of the volcanic rocks. The presence of the absorption features at 6.5 and 11.5 μm clearly indicate the carbonate nature of the dolomite example.

FUTURE PROSPECTS

We will evaluate the geologic utility of multispectral thermal infrared data using TIMS, and we will determine the lithologies that can be effectively discriminated on the basis of TIMS measurements, either alone or in combination with other remotely sensed data sets. Our laboratory studies will be directed towards understanding the spectral emission behavior of Earth surface materials so as to optimize the interpretation of TIMS data.

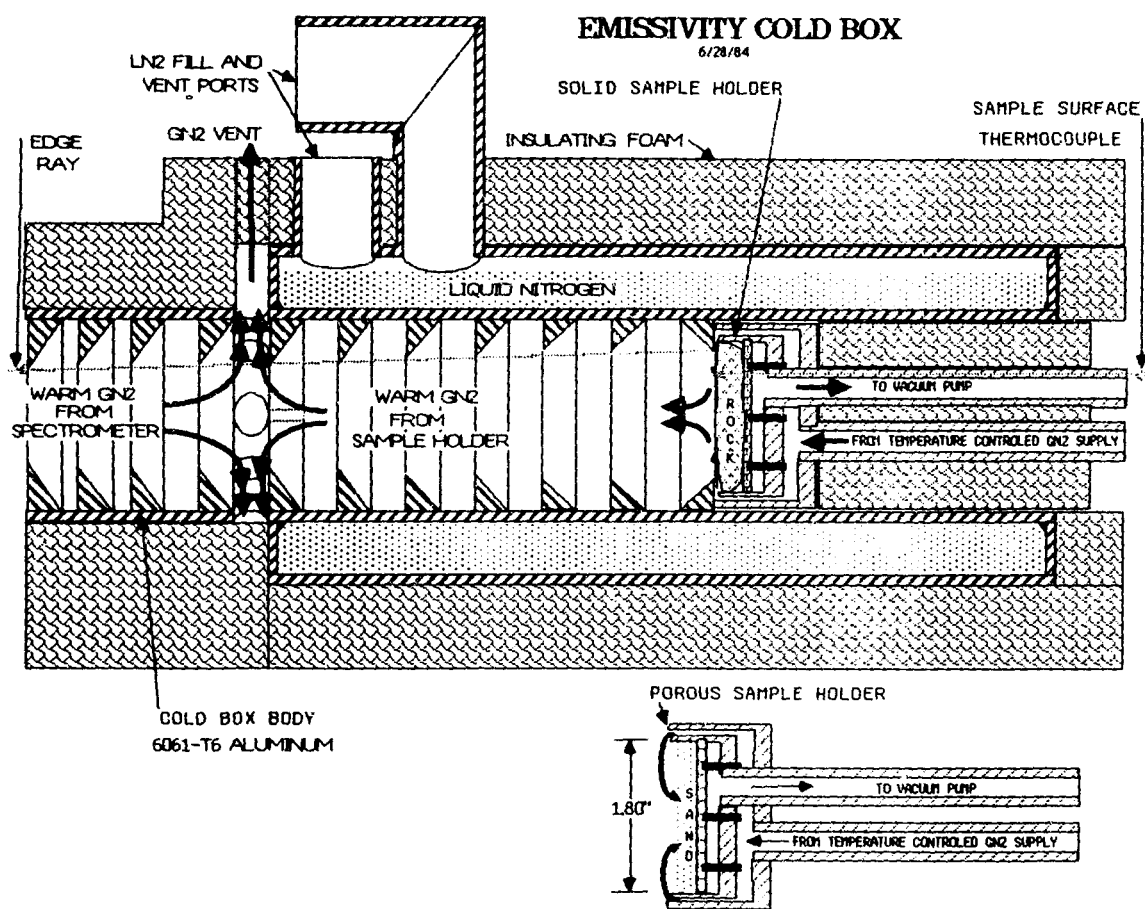


FIGURE 1. DETAILS OF EMISSIVITY COLD BOX AND SAMPLE HOLDER.

GN2 = GASEOUS NITROGEN, LN2 = LIQUID NITROGEN.

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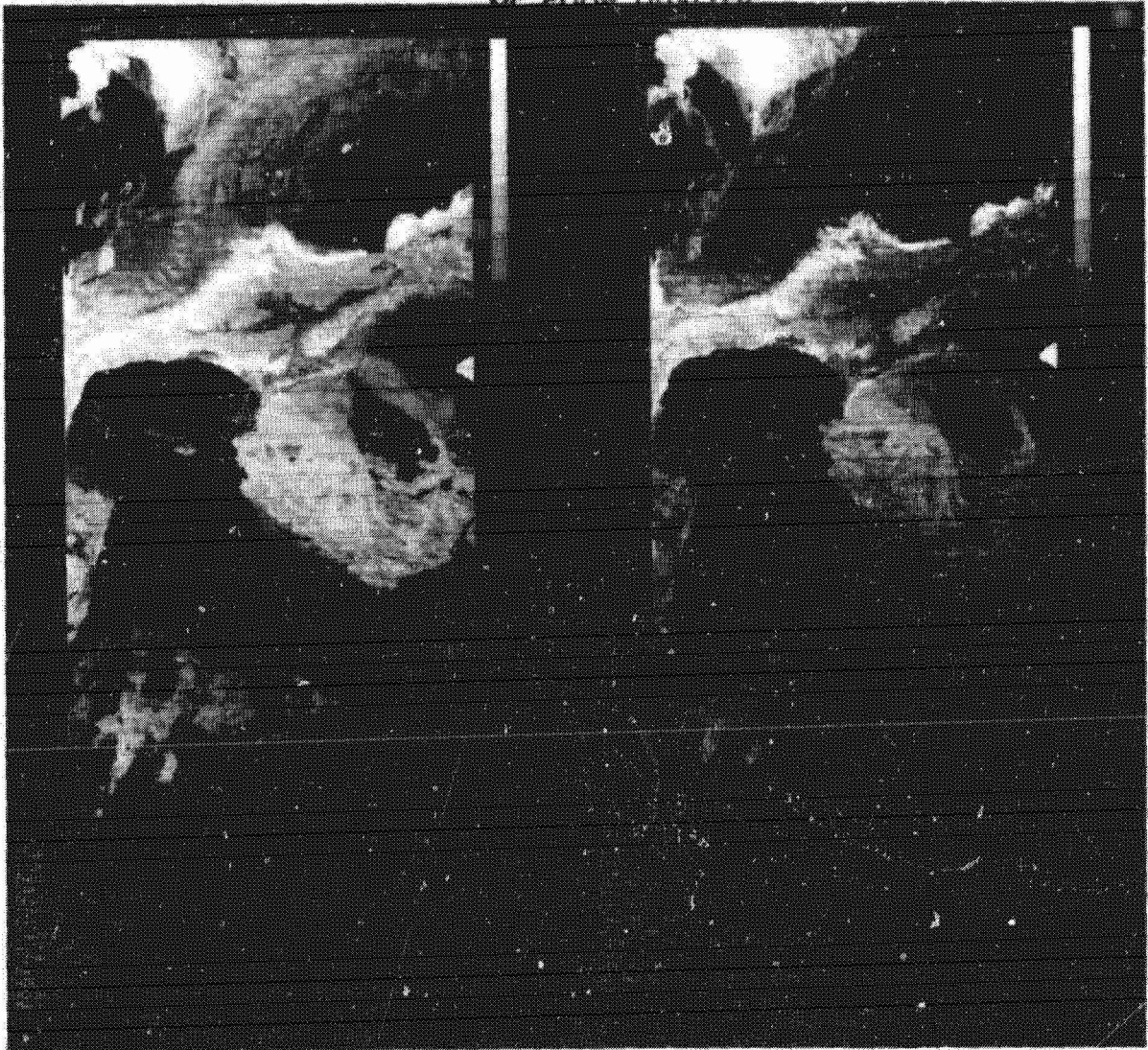


FIGURE 2. VARIATION IN GROUND SURFACE EMITTANCE IN DEATH VALLEY, CALIFORNIA, AS DETERMINED FROM CALIBRATED TMS DATA AND PLANK'S LAW. IMAGE 2A WAS DERIVED FROM CHANNEL 3 DATA (WAVELENGTH RANGE = 9.0-9.4 MICROMETERS) AND 2B COMES FROM CHANNEL 4 DATA (WAVELENGTH RANGE = 9.6-10.2 MICROMETERS). THE IMAGE AREA INCLUDES PART OF THE FUNERAL MOUNTAINS (TOP), VALLEY FLOOR (CENTER) AND PART OF THE PANAMINT MOUNTAINS (BOTTOM).

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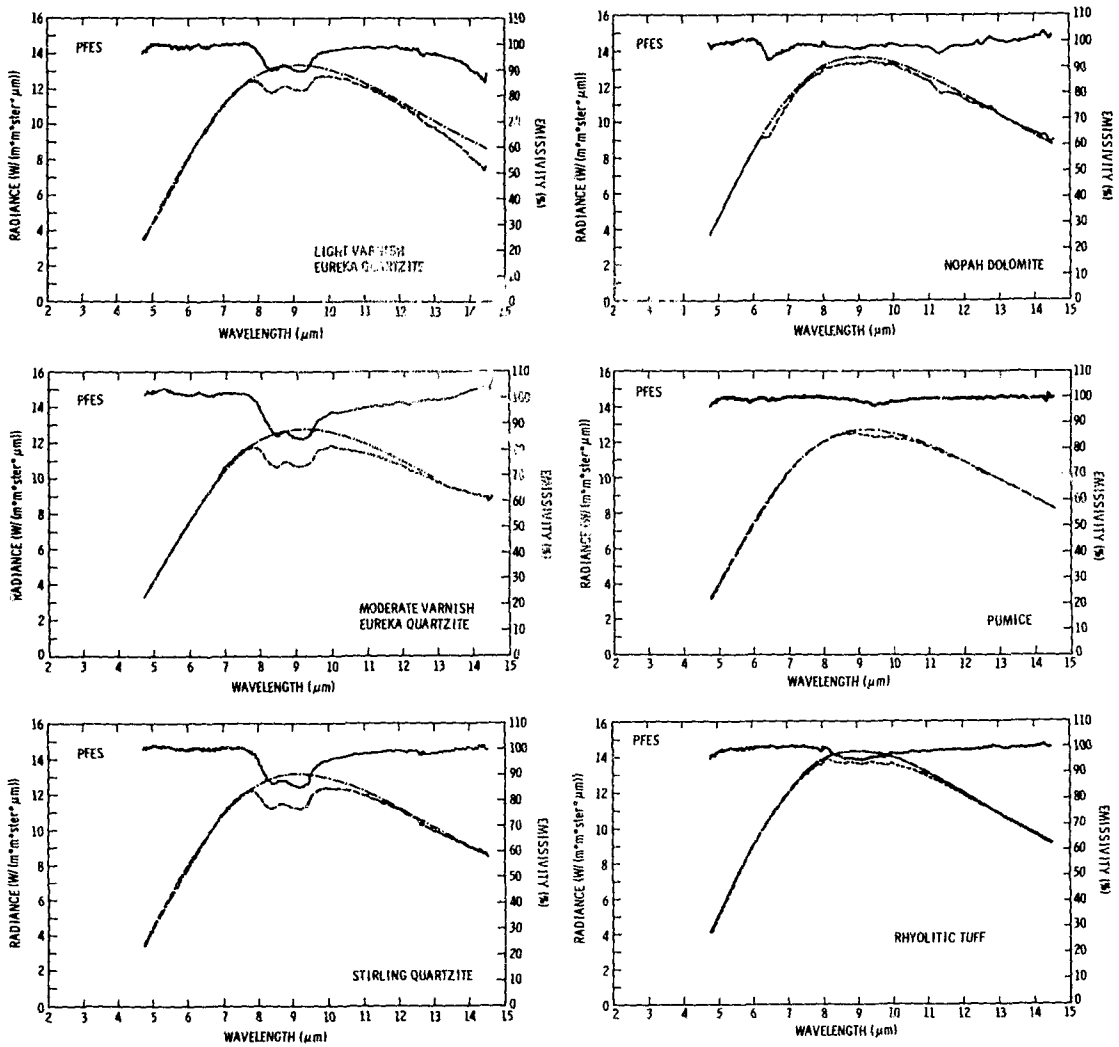


FIGURE 3. NORMAL SPECTRAL RADIANCE AND SPECTRAL EMISSANCE OF ROCKS FROM DEATH VALLEY, CALIFORNIA, AS DETERMINED BY THE PFES.

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