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Reflectance Spectra of Gypsum Sand from the White Sands National Monument and Basalt from a Nearby Lava Flow

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Abstract

The White Sands National Monument in southern New Mexico and a nearby basalt lava flow are both readily visible to earth satellites. Because of the current interest in remote sensing of the earth's resources and atmospheric environment, the visible and near infrared reflectance of these formations was investigated. Diffuse reflectance spectra in the 0.4 to 2.5 micrometer spectral interval are presented and discussed. The maximum contrast between these features occurs at a wavelength of 1.1 micrometers, where the reflectance of the white sand is about 75 percent, while that of the basalt is about 7 percent.

Introduction

The White Sands National Monument in Otero County, New Mexico, consists of several hundred square miles of nearly pure gypsum ($CaSO_4 \cdot 2H_2O$) in the form of clean, transverse sand dunes and flat beds of gypsum sand. The extent and purity of this deposit is sufficient to make it a highly unusual, if not unique, geological formation. With the advent of earth satellites, this natural feature has taken on an additional significance. Because of the size of the white sand deposit and the relatively high proportion of cloud-free days in southern New Mexico, the White Sands National Monument is often clearly visible from earth orbit. Photographs from both manned and unmanned satellites show it as a readily distinguishable light spot. Located just a few miles north of the White Sands is a recent, nearly black, basalt lava flow which is also visible in satellite photographs. Both features are shown in Figure 1. Because of the current interest in remote sensing of the earth's resources and surface environment, and the close proximity of these two contrasting formations, it is of interest to investigate their visible and near infrared reflectance. This report presents diffuse reflectance spectra in the 0.4 to 2.5 micrometer region of samples taken from these formations.

Measurement Technique

The total reflectance measurements were made with a Cary model 14 spectrophotometer equipped with the manufacturer's 25 cm integrating sphere, as described by Hedelman and Mitchell (1968). The relatively small component of specularly reflected energy was not deliberately excluded from the measurement, as is sometimes done with this accessory. Because of low reference beam energy, the instrument was run with maximum slit width in the 2.1 to 2.5 micrometer spectral interval. Near 2.2 micrometers the signal-to-noise ratio was not satisfactory due to the glass transmission optics of the instrument. The dotted region in the reflectance curves presented in Figure 2 is intended to indicate this fact. Below 2.1 micrometers the instrument was operated with a very satisfactory signal-to-noise ratio. Because of the variation of slit width with wavelength in the Cary 14, the spectral band width increased from a minimum of 5×10^{-4} micrometers in the visible spectrum to a maximum of 9×10^{-3} micrometers at longer wavelengths.

Samples taken from the surfaces of dunes and playas were held in sample dishes approximately 3 cm deep during reflectance measurements. In the case of basalt samples, measurements were made on a flat, weathered surface of the rock. The refer-

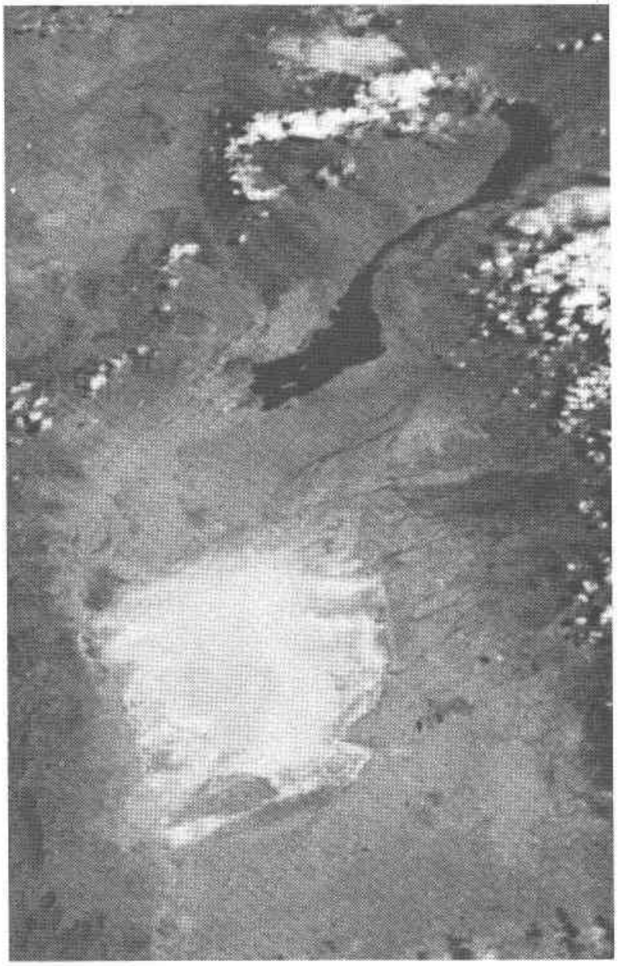

FIG. 1. This oblique view, looking north, is part of a NASA Gemini V photograph. The light circular area is the White Sands National Monument gypsum deposit, which is roughly 20 miles in diameter. The dark basalt flow extending from south west to north east in the upper part of the photograph is about 45 miles in length. The smaller white areas are clouds over nearby mountains.

ence standard used was highly refined barium sulfate[1], so the curves presented here express the diffuse reflectance of the sample as a percentage of the diffuse reflectance of the barium sulphate standard. The absolute diffuse reflectance of similarly prepared barium sulfate has been reported by Grum and Luckey (1968).

Specimens were collected during normal dry periods as much as possible, and their reflectances were measured as soon as possible after collection. However, several sand samples obtained just after a period of heavy precipitation were noticeably moist, and since this results in a lower than normal reflectance, these were allowed to dry at room temperature for 24 hours.

[1] The barium sulfate reference material was "Eastman White Reflectance Standard," available from Eastman Kodak Company, Rochester, N.Y.

Results and Discussion

Fourteen samples from the White Sands area and three from the south end of the basalt lava flow were collected. Typical examples of reflectance spectra of these samples are shown in Figure 2.

The reflectance of one sample of dune sand is shown in Figure 2 along with the reflectance of reagent grade $CaSO_4 \cdot 2H_2O$. Comparison of the qualitative features of these spectra makes it clear that the dune sand is nearly pure gypsum. The absorption bands indicated by the reflectance minima in these curves are due to the water inherent in the gypsum crystal structure. They are all overtone or combination tones arising from the three fundamental vibration frequencies of the water molecule, as modified by the crystal structure. Anhydrous $CaSO_4$ does not show any significant absorption bands in this spectral region. A comprehensive study of the effect of structural water on the spectrum of gypsum and similar minerals has been made by Hunt, Salisbury, and Lenhoff (1971).

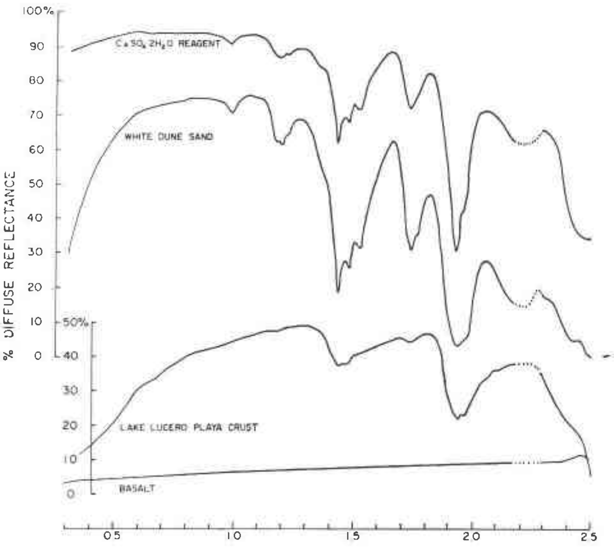

FIG. 2. Diffuse reflectance spectra of reagent grade $CaSO_4 \cdot 2H_2O$ along with typical examples of white gypsum sand, Lake Lucero playa crust, and basalt. The curves have been smoothed to eliminate spectrophotometer noise and baseline effects.

Figure 2 shows that reagent grade $CaSO_4 \cdot 2H_2O$ had a higher reflectance than the gypsum sand. For the most part, this is because the reagent had a much finer particle size than the sand. However, it may be seen that in the short wavelength visible spectral region, the reflectance of the sand drops off much more rapidly with decreasing wavelength than does that of the reagent. This is an indication of slight contamination of the sand by desert soil particles. Soil samples have a diffuse reflectance that is very low in the ultraviolet, but increases with wavelength throughout the visible spectrum (hence the brown color), flattening off in the near infrared. Because of this, the effect on the white sand reflectance caused by soil contamination is greatest at short wavelengths.

The reflectance curve in Figure 2 for white dune sand can be considered typical of the White Sands area. Variations of reflectance with sample locality on the order of 5 percent were found. This curve is also reasonably representative of samples taken from the large flat area of compact gypsum in the northwest part of the deposit. Samples taken from this area had reflectances a few percent lower than the dune sand, but were otherwise similar in spectral character.

Southwest of the white sand deposit are two playas collectively known as Lake Lucero. During periods of high rainfall, these areas collect and hold runoff water for several months. Figure 2 shows a reflectance curve for a sample of surface crust taken from one of these areas during a dry period. The spectral contrast is much lower for this material, because it is composed of gypsum heavily contaminated with soil as well as other more soluble playa minerals.

Samples of basalt were taken from the lava flow approximately 35 miles northeast of the white sand deposit. All exhibited a very low reflectance with no significant spectral structure (Fig. 2). One can see that this basalt is nearly as "black" in the infrared as it is in the visible spectrum. This curve is typical of the reflectance of the exposed weathered surface. A freshly fractured surface will show a slightly higher reflectance.

It is interesting to compare the general characteristics of the reflectance spectra of these two geological features. The reflectance of the white sand deposit has a strong wavelength dependence due to its hydrated composition, while the reflectance of the nearby lava flow is very low at all wavelengths. At about 1.92 micrometers, the reflectance of both these features is very low (less than 10 percent), while at about 1.10 micrometers the reflectance of the white sand is about ten times as high as that of the lava flow. Note that the neodymium laser, a potential remote sensing tool, operates at a wavelength of 1.06 micrometers. The reflectance at this wavelength for the gypsum sand is about 75 percent, while that of the nearby basalt is about 7 percent. This high degree of reflectance contrast between two neighboring stable natural landmarks suggests the possibility of measuring local atmospheric turbidity by comparing the apparent reflectances as seen by an earth satellite.

Acknowledgment

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