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2002, pp. 353-355. https://doi.org/10.56577/FFC-53.353

in:

Geology of White Sands, Lueth, Virgil; Giles, Katherine A.; Lucas, Spencer G.; Kues, Barry S.; Myers, Robert G.; Ulmer-Scholle, Dana; [eds.], New Mexico Geological Society 53rd Annual Fall Field Conference Guidebook, 362 p. https://doi.org/10.56577/FFC-53

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New Mexico Geological Society Guidebook, 53rd Field Conference, Geology of White Sands, 2002, p. 353-355.

WHITE SANDS, NEW MEXICO, AS PART OF AN IMAGE-PROCESSING LABORATORY

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Abstract.— The present report summarizes results from Landsat 7 ETM+ and ASTER imagery from several sites in the White Sands – Lake Lucero region. Gypsum to clay to sodium sulfate + halite mineralogical zoning is present to the northwest of the visitors area of the White Sands National Monument. Samples along a traverse within the gypsum dunefield have a measured grain size variation and laboratory based reflectance spectral determinations of these samples show changes that, because of the control of variables in the experiment, can only be associated with grain size variations. In addition to the goal of saline soil characterization, mapping of playa regions can provide immediate information relevant to regional groundwater hydrology and quality, and mineral resource possibilities.

INTRODUCTION

Saline soils constitute a worldwide agricultural problem and a limited knowledge base impairs its prevention and remediation. Salt identification, distribution, abundance, and temporal variations are fundamental parameters. Evaporite precipitation in playa environments is an end member, an extreme, of the soil salinity problem. The present initiative to address soil salinity issues is first through the study of evaporites, where methodology development can take place with fewer variables and better characterization. Techniques for mapping of the mineralogy, concentrations in mixtures, grain size, and influences of humidity are being developed. Saline soil studies will eventually have to test the methodology at lower salt concentrations.

The quantitative utilization of remotely sensed and ground based multi and hyperspectral reflectance measurements depends on calibration. The White Sands has frequently been used in such spectral studies by airborne and spaceborne platforms, often for calibration to absolute reflectance measurements and other parameters (Lindberg and Smith, 1973; Moran et al., 1995; Thome, 2001). This site provides very high reflectivity over several wavelength bands of interest. Quartz sand does not have this same high reflectivity. With the onset of hyperspectral data acquisition, the measurement of additional variables, such as grain size, characteristic of the target may become detectable. The testing of this idea is part of the objective of the present investigation.

Presented here is an expanded use of the White Sands as a test site for the evaluation of gypsum grain size variations and mineralogical mapping using remote sensing imagery. In a previous initiative, reflectance spectra (400 to 2500 nm) were determined from laboratory controlled samples of varying mineralogy, mixtures, and grain sizes to serve for image calibration (Howari et al., in press). This study is part of an extended project directed towards mapping and developing a better understanding for the formation of evaporite deposits and saline soils. Spectral responses of laboratory samples prepared under controlled variables are reported. Samples included 5 evaporite minerals plus clay. Mixtures have also been investigated, as well as grain size variations in several instances. Samples have been prepared by mechanical mixture, and by the mechanism of evaporation of the salts onto soil grains. Such background work provides laboratory documentation of peak intensity, slope changes, and other features, as a function of these variables. The salts investigated were calcite, gypsum, thenardite, halite and nahcolite.

Prior mapping of different evaporite minerals in the Lake Lucero – White Sands region is limited to one MS thesis (Allmendinger, 1971). The present report results in a gray scale image of regional mineralogical zoning of surface evaporites and clay, and summarizes several additional observations with spectral interpretations based on several ground truth samples. Initial processing of AVIRIS data will provide information that will lead to judicious site selection for additional ground truth studies. A small database exists for evaporite mineralogical mapping on a global scale (Garrett, 2001). This is a part of a larger study of reflectance spectroscopy directed towards the problems of saline soil encroachment and evaporite mineral formation, which are problems of major agricultural concern (Ghassemi et al., 1995).

BACKGROUND

Laboratory based hyperspectral studies between 400 - 2500 nm for evaporate minerals (Crowley, 1991,1993) indicate that the spectra of many minerals are distinguishable. Ground based mineralogical mapping is possible, and some multispectral remotely sensed data have proven useful (Sharma and Bhargava, 1988). With the evolution of hyperspectral data acquisition, mineralogical identification can accommodate a larger number of species (Green et al., 1998; Taylor and Rem, 2001). The potential of hyperspectral studies leads to the idea that measurement of grain size variations or mixtures can be made with its increased spectral resolution and radiometric accuracy and precision. Spectral determinations of mineralogy are carried out almost routinely and mixture determinations have been made in several instances (White and Drake, 1993).

With respect to the White Sands region, Allmendinger (1971) mentioned the distribution of the evaporite minerals gypsum, thenardite and halite at Lake Lucero. Basabilvazo et al., (1994) and Barud (2000) studied the regional groundwater properties of the area. Langford (this volume) reports on playa shorelines, and some of his eolian gypsum samples play an important part of this investigation.

PRESENT STUDY

This paper represents the initial findings of a much larger investigation in the White Sands – Lake Lucero region. The large-scale project involves a number of sites in the study area and analytical techniques. All sites involve image processing using data from different platforms (e.g. LANDSAT 7, AVIRIS, ASTER). Important to all studies is the ability to provide ground truth samples and the existence of data from remote sensing platforms. Sites with ground truth samples require mineralogical and grain size analyses, and reflectance spectra on site and/or on samples in the laboratory. This report only presents results on two initial experiments.

The Langford sample collection (15 eolian sand samples) was used because it is of homogeneous mineralogy (gypsum); a small measured grain size variation along a 4 km traverse, lack of vegetation along the traverse, and samples located at the same elevation with respect to intradune valleys (Fig. 1). They were sampled, under permit, on a traverse to the northwest of the loop for tourist visitors in the White Sands National Monument. Their reflectance spectra were determined in the laboratory with a GER 3700 spectrometer. ASTER and Landsat 7 ETM+ images of the White Sands region are available through PACES (Pan American Center for Earth and Environmental Sciences) where they have been classified by principal component analysis.

RESULTS

Reflectivity values, determined from the Langford samples, for two specific gypsum spectral peaks with strong R^2 values are plotted against distance along the traverse (Fig. 2). Measured Phi values are also provided. Phi and reflectance have a high correlation, whereas Phi with distance is slightly more scattered. Peaks P1 (950 nm) and P2 (1150 nm) record the documented grain size variations in these field samples. P1 is commonly used in gypsum studies. Four other peaks tested (Table 1) do not give reliable results. Peaks P1 and P2 will initially be used to test AVIRIS data for grain size response. The relationship between the spectral reflectance versus distance along transect is shown in Figure 2. The spectral measurements are conducted using GER 3700. To analyze the relationship between the reflectance and distance, different peaks are selected. The selected wavelengths are 0.99 μm (P1), 1.17 μm (P2), 1.43 μm (P3), 1.78 μm (P4), 1.94 μm (P5), and 2.21 μm (P6). Table 2 shows the governing equations between the reflectivity of gypsum at selected wavelengths and the distance along transect. The results show R^2 between the spectral reflectance and distance range from 0.22 to 0.92. P1 and P2 show strong linear relationship. Therefore, these two peaks are used to show the reflectance variations with distance along transect. The results exhibit that the spectral reflectance increases with distance. This can be ascribed to the decrease in grain size of gypsum.

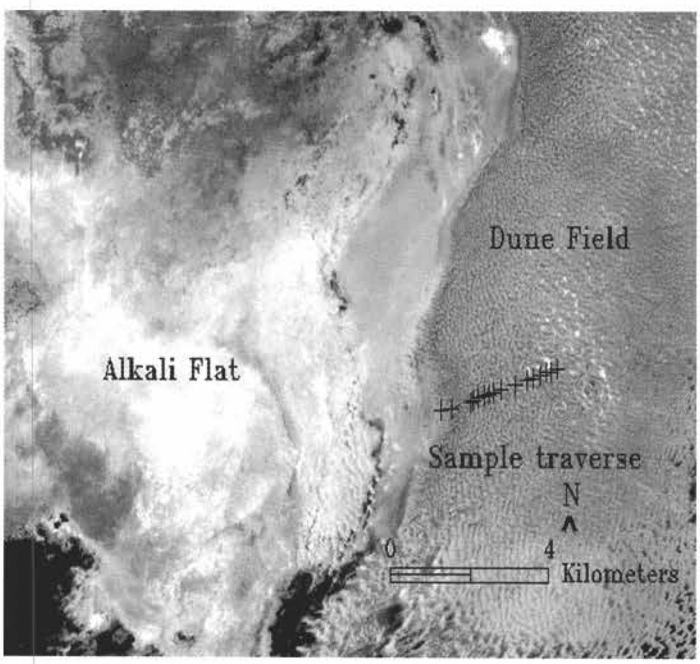

FIGURE 1. Location map of experiments 1 and 2 in the White Sands region. The sample traverse is west of the visitors area in WSNW, and mineralogical variations are noted between there and Alkali Flat. The image gives the principle componet analysis of Landsat 7 ETM+ data; gray scale image of PC2.

Principal component analysis (PCA) and hue, saturation, value analysis (HSV) were carried out on ASTER and Landsat 7 ETM+ data from the region, with particular attention directed to a path between the WSNM visitors area (the site of the Langford samples) in the dune field, to the west into the Alkali Flat area (Figure 1). This activity to test mineralogical mapping has been successful. Brightness variations can be seen in Figure 1 along this path and these different areas are characterized by different statistical components. Spectral comparisons are made with gypsum in the dunefield, clay to the west, and halite/thenardite in Alkali Flat. Figure 1 has been created so as to diminish/negate gypsum, and thus better define mineralogical zoning to the west. Curving paleoplaya shorelines (Langford, this volume) are clearly visible to the west and north of the major dune area, and appear to influence mineralogical zones.

The most intractable problem for regional mapping is the paucity of distinguishing features in the spectra of halite and thenardite (sodium sulfate), and the fact that these two minerals are frequently spatially associated. Across their band of high reflectivity, the spectrum of halite has a small negative slope, whereas the spectrum of

TABLE 1. The governing equations between the distance along transect (X) and reflectivity (Re) of the Langford gypsum samples collected from White Sands Dune Field (Fig. 1).

Peak	Equation
P1 (0.99 μm)	Re=0.0044X+52.209; R^2=0.9236
P2 (1.17 μm)	Re=0.0025X+47.843; R^2=0.8519
P3 (1.43 μm)	Re=0.0006X+17.47; R^2=0.4221
P4 (1.78 μm)	Re=0.001X+21.629; R^2=0.6347
P5 (1.94 μm)	Re=-0.0001X+6.0387; R^2=0.1317
P6 (2.21 μm)	Re=0.0001X+9.2089; R^2=0.2212

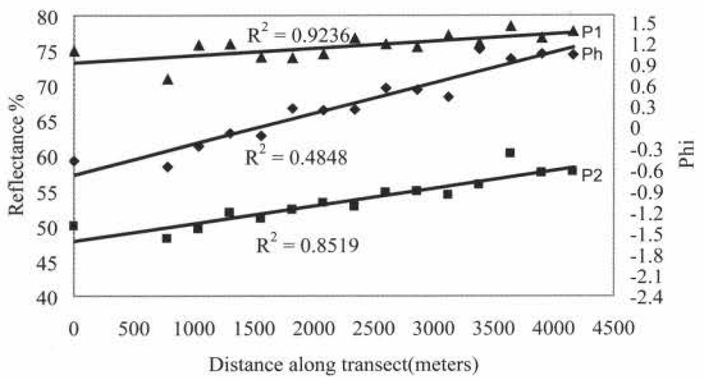

FIGURE 2. Spectral reflectance and Phi versus distance along transect (meters). Triangles represent P1, diamonds Phi and squares P2

thenardite has a small positive one. The potential for resolving these individual spectra utilizing these slope parameters is being tested in addition to procuring additional ground truth samples.

A number of interesting features that require further study have been recognized. Grain size variations for the Langford samples are between 354 and 693 micrometers. Can this grain size variation be used to calibrate grain size sensitive properties of gypsum spectra? In addition, a distinction between wind blown gypsum versus that of evaporite or bedrock origin also needs to be determined. Careful sample investigation sometimes reveals a paragenesis of evaporate minerals. Can variations in paragenesis be recognized in spectral studies. If so, does such a paragenesis exist at Lake Lucero or Alkali Flat? These types of questions also might relate to the larger questions of how primary evaporite zoning relates to regional hydrology.

CONCLUSIONS

1. Two gypsum spectral peaks determined from laboratory study of field samples respond reliably to grain size variations within the study area.

2. Mineralogical zoning is mapped from the visitor's area of the WSNM to the west, characterized by a sequence of gypsum, clay, and then halite/thenardite.

3) Ability to map evaporites via remote sensing spectral analysis shows potential to be an important tool in soil salinity studies, for the determination of regional hydrology of arid regions, and for mineral resource development.

ACKNOWLEDGMENTS

Resources and expertise of PACES (Pan American Center of Earth and Environmental Studies) have helped to make this project possible. The junior author acknowledges support from CERM (Center for Environmental Resource Management). Bernard E. Hubbard, US Geological Survey, Reston, VA, and Richard P. Langford, Dept. of Geological Sciences, UTEP, served as conscientious reviewers and are thanked for their constructive comments. Our present state of knowledge of this topic was arrived at with prior collaboration with Drs. Seiichi Miyamoto and Fares Howari of the Texas A & M Agricultural Experiment Station, El Paso, TX.

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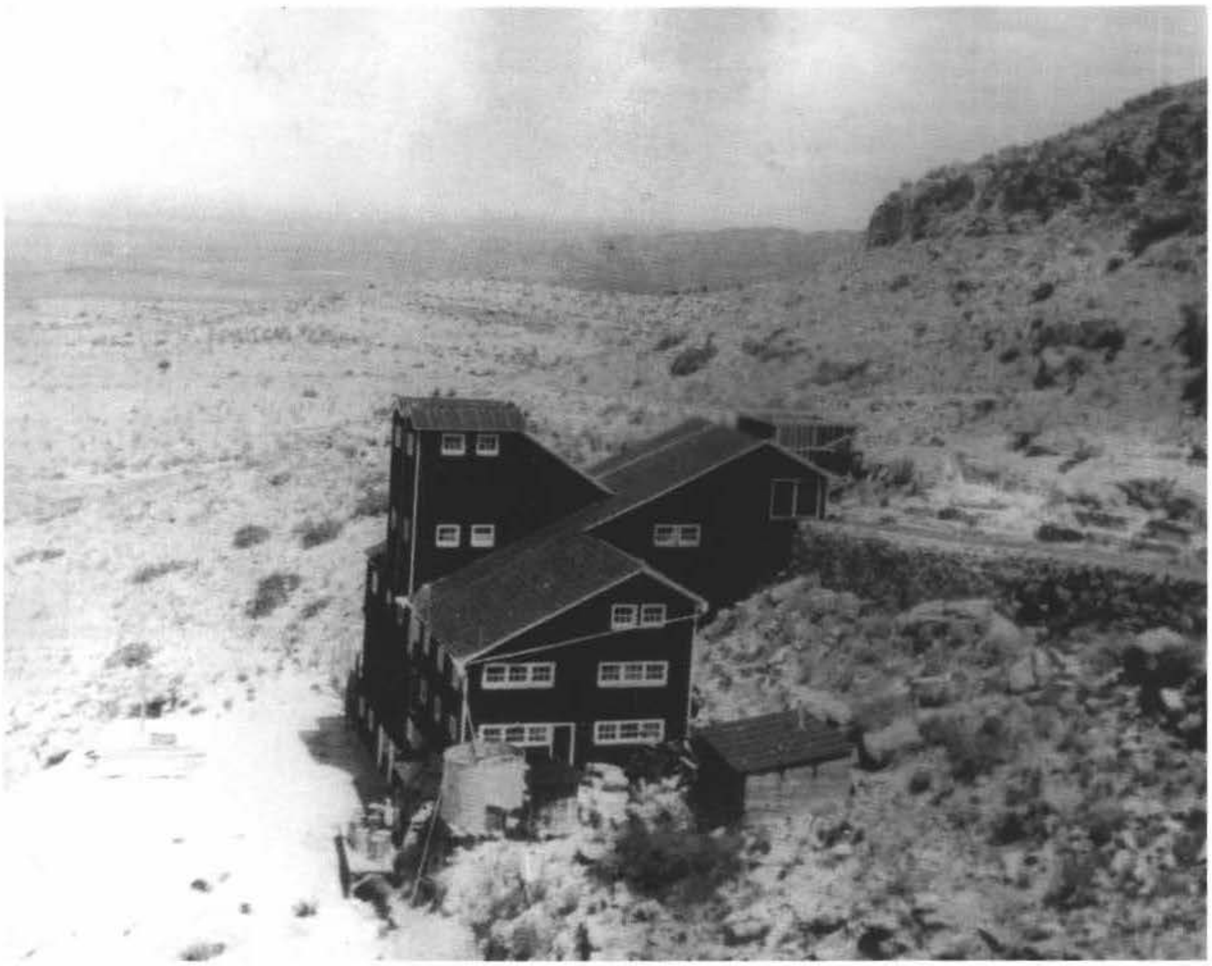

The Western General Mineral Products Company acquired the Hansonburg lead properties in 1916 and made the first attempt to systematically develop the deposits. The company invested $150,000 in mine development, surface rail tramway, and the 50-ton per day dry concentrating mill, shown above. The mill proved unsuccessful and the operation was abandoned after producing just 76,775 pounds of concentrate containing 67.4% lead and 3.7 ounces silver per ton. The name "Old MacCarthy Lead Mine" derives from this period when Marion S. MacCarthy was manager. NMBG&MR Photo Collection, No.1828; photographer unknown. Caption courtesy of Robert Eveleth.