Interpretation of spectral differences in alluvium of Big Bend National Park, Texas, through the use of Landsat satellite images

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INTRODUCTION

Big Bend National Park was chosen for a geologic study using Landsat satellite data. This is an arid region with little vegetation to cover the geology. Youthful volcanism, structural deformation, and arid region geomorphology are well exposed in this terrain of high relief. Through various image processing techniques, three dramatic spectral differences appeared in the alluvium below the Sotol Vista Overlook just west of the Chisos Mountains. These different deposits are shown on all geologic maps of the park as the same. The purpose of this study was an attempt at understanding the reasons for this alluvial material to yield such spectral inconsistencies from the known geologic information.

METHODS

Adobe Photoshop, MultiSpec, and Band Aid are the applications which were used to combine the Thematic Mapper bands using the techniques of band ratioing and principal components analysis. Bands resulting from these new combinations produced three divisions defining areas of spectral similarity, which are referred to here as A (northern sediments), B (middle sediments), and C (southern sediments).

Band Ratioing is the process of performing various algebraic functions between two bands of choice, resulting in enhanced data. For example, iron oxide content can be visually enhanced by dividing the pixel value DN of band 3 (red light in the visible spectrum) by the corresponding DN of band 1 (blue light in the visible spectrum). Spectra of weathered iron minerals have a low spectral response to blue light, and a high response to red light. By dividing 3 by 1, most other aspects of an image will be canceled, since they will show a similar response to light having a wavelength in the red or blue part of the spectra. The created band will emphasize iron oxide content, since, as a result of the division, all else will have a uniform ratio. This same process will work for other minerals which show a great difference in the spectral response to light of different wavelengths. Various combinations of band ratios were used including 3/1, 5/1, 5/7, 4/7, 4/5, 5/7, and 3/4*5/4 to yield information into the reasons for spectral differences. Although differences appeared, the information was not of significant value.

A principal components analysis is another way to separate certain aspects of an image. Principal components is a way to remove the redundant information in the seven bands in an attempt accentuate the differences. To accomplish this, MultiSpec plots the DN of all the pixels in multi-dimensional space. From here, the software rotates the original axes of the plots at 90 degree angles to fit the means of the original plots. The 7 bands in the original Landsat image are rearranged into 7 new bands representing the 7 principal components. The first component accounts for the greatest variance. Usually, the first four components account for almost 100 percent of the variance and the remaining components can be ignored. This in effect condenses the vital information of all seven bands into four. With fewer bands to look at, the interpretation of differences becomes significantly less involved. Using principal components, images of the alluvium could be generated in bright shades of red, yellow, and blue.

To verify and interpret reasons for the spectral differences, some laboratory techniques were also employed. A spectra radiometer was used to record spectral data from collected samples in the lab, and abstract the mineralogic composition of the soils. X-ray diffraction was another technique employed to identify the mineral components. An energy dispersive spectrometer was used to obtain characteristic spectra of the elements to evaluate the validity of minerals selected on the basis of x-ray patterns.

OBSERVATIONS

All the geological maps and soil maps list the alluvial fan located between Burro Mesa and Goat Mountain of the Big Bend National Park as only one type of soil. The three distinct color areas could be due in part to composition, texture, or vegetation. One image in which the responses were quite distinct was the TM 531 image in which band 5 was represented in red color, band 3 was represented in green, and band 1 was represented in blue. The northern portion of the fan, or area A, appeared to have a light blue and pink response. Area B had a response of a darker teal blue with some pink. Finally, area C, the southern most section, seemed to display only a very light

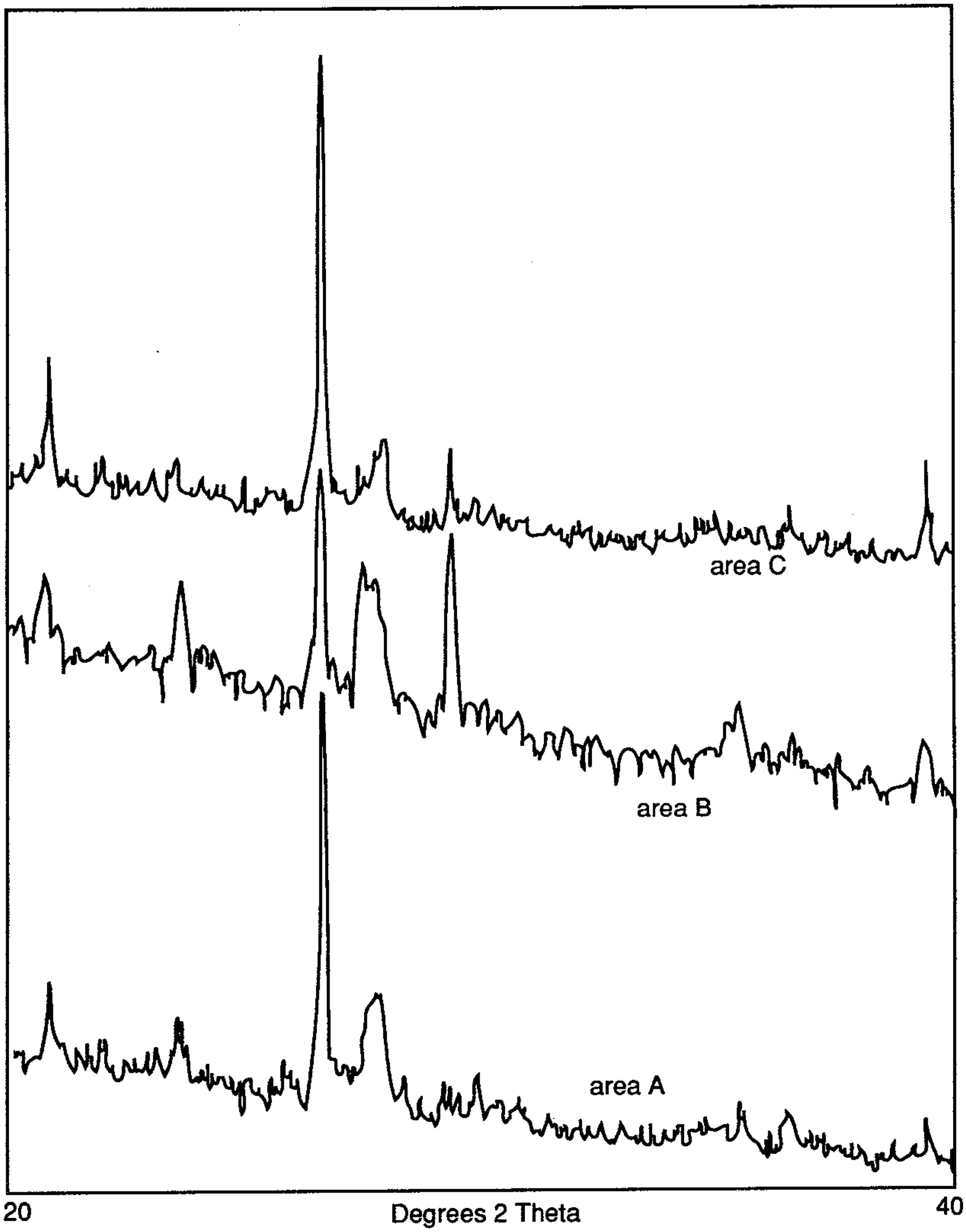

Fig. 1 - X-ray diffraction patterns of areas A, B, and C.

pink to white response. The 531 image also allowed for the tracing of the sediments up stream to possible provenance. Area A and the Quaternary consolidated gravel of Burro Mesa showed very similar response. Another Quaternary gravel deposit, the Sotol Vista Overlook, spectrally matched area B. The provenance for area C may have been the pyroclastic sediments from the Tertiary Chisos Formation along the Blue Creek Canyon.

Closer observation from a ground truth of the area offered some more clues into the spectral differences in the sediments. The soil of area A ranged in size from clay particles to rock fragments 2-5 cm in length. Scrubby, brown, waist-high vegetation dominated the area. Area B soils looked similar in composition and texture, but tuff and basalt cropped out sporadically in the section. The vegetation was taller, though, and green bushes were common here. The soils of C had slightly more gravel of a finer texture than A and B, and the soil was packed much harder. Vegetation in area C was comparable to that of area A. Samples were taken from the three alluvial deposits for a lab-induced spectral response.

The plots from the x-ray diffraction show that the soils have slightly different mineral compositions. All the soils contain orthoclase and microcline, but the exact assemblage of each soil could not be determined in the time allotted. A peak search turned up numerous cards for exotic minerals, and a check using EDS spectra eliminated some on the basis of absence of necessary elements. Further treatment of the samples is needed to break down the exact components. (see fig. 1)

DISCUSSION

Through all of the processes mentioned above, the conclusion is the three drainages of the alluvial fan are different. The first major clue from the ground is the varied vegetation. Certain plants prefer to grow under specific mineralogical settings, so the differences in the plants in the areas may indicate the soils of the three drainage areas have separate provenance.

In the lab, the use of the spectra radiometer and x-ray diffraction confirmed compositional differences. The alluvial materials have slight mineralogical variance. This, probably in combination with vegetation and texture, contribute to the distinguishing spectral signatures.

The readouts of the principal components parameters gave clues to the reasons for the causes of the spectral changes from one area to another. (see fig. 2) PC band 1 gathered most information from TM bands 5 and 7, each important in detecting mineral composition. This leads one to believe that PC band 1 accentuates composition of the soils. The second PC band received the majority of its data from TM band 1 (blue light) or shadow differences. Due to this knowledge, PC band 2 is thus interpreted as a record of the texture of each soil. Finally, even though the vegetation coverage was slight, the radiation it emitted seemed to be great enough to register as PC band 3, receiving the most data from band 4, the near thermal infrared.

Component1	Channel 1	2	3	4	5	7
2	0.42836	0.25816	0.42548	0.27446	0.57350	0.40571
3	0.54493	0.25166	0.38555	0.03714	-0.66040	-0.23143
4	-0.24337	0.02493	0.04566	0.85986	0.03931	-0.44403
5	-0.38334	-0.06547	0.19029	0.27637	-0.46689	0.71985
6	0.52282	-0.15951	-0.71928	0.32615	-0.11912	0.25157
7	-0.20009	0.91634	-0.33861	-0.03440	-0.03536	0.05656

Fig. 2 - Principal component eigenvectors

Using the standard Landsat image combinations (see TM 451 color plate) also yielded much information. Enhancing the images clarified the drainage systems. This clarification allows one to trace the alluvium by colors along the drainage systems back to the possible provenance. Interpretation of such is very difficult with aerial photographs or through study on the ground.

Although this study revealed some of the impact Landsat images have in geological research, much work is left to be followed up on in this project. The soils need more detailed compositional studies to isolate the exact mineralogical content. Samples from the possible provenance can also be gathered and studied with x-ray diffraction or ICP, noting if the compositions match up with the alluvium. If similarities arise, the provenance can also be studied spectrally to understand the extent of texture and vegetation altering the radiation Landsat detects. Finally, the vegetation can be studied to reveal distinct spectral signatures. The lack of time available was a main barrier from attempting these other areas of research.

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THE USE OF LANDSAT IMAGERY TO DOCUMENT LAND USE CHANGES IN THE GALVESTON BAY AREA, TEXAS

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INTRODUCTION

The focus of this project was to use Landsat thematic imagery to analyze land use changes. This project focused on the Galveston Bay area on the coast of Texas; this area was chosen because both man made features and natural environments are present. Processing techniques, such as clustering and supervised classification, were used to create a thematic map. The goal of this project was to determine the urban growth over approximately a decade by comparing the thematic maps from the 1985 image to earlier maps of the area.

IMAGE PROCESSING

This project processed a Landsat image of the Galveston Bay area. From the raw Thematic Mapper (TM) bands, a 3,2,1 true-color and a 4,3,2 false-color, infra-red composite were created. The 4,3,2 composite was used to highlight the difference between vegetated and urban areas. This combination was also particularly useful in defining water boundaries and differentiating between the varying water depths. (See Color Plate 4)

CLASSIFICATION

Classification is a processing technique that creates a thematic map from the bands of an image. Two pixels that both represent the same type of area could have different DN numbers due to subtle differences in the thirty by thirty meter area they represent. Classification techniques attempt to group together pixels which represent the same land cover, such as a marsh, and assign a single DN value to every pixel in that group. This DN value and all pixels that have this DN value are then associated with that type of land cover. To determine which pixels can be grouped together, they are plotted in multispectral space using each pixel's DN values as coordinates. Multispectral space is created by mutually perpendicular axes, which each represent a single TM band. There are two types of classification: unsupervised and supervised. In unsupervised classification, the algorithms determine the natural groups among the data. Supervised classification involves the analyst defining the groups and then the algorithm determines how well the data fit into them.

Unsupervised Classification Methods

This project used both isodata and single pass algorithms for the unsupervised classification. The isodata algorithm evaluates each pixels individually and assigns it to the closest initial cluster center. Once every pixel has been assigned to a cluster the computer takes each of the resulting clusters and determines its center. The algorithm then reevaluates and assigns each pixel in terms the newest centers. This process is repeated until an iteration is performed in which a specified number of pixels did not have to be reassigned to a new cluster. This percentage of pixels is the minimum convergence and is a parameter that must be set by the analyst. Other parameters specified by the analyst are the number and location of the initial cluster centers.

In contrast to the isodata, the single pass algorithm analyzes each pixel only once. The first pixel in the first row is designated as a cluster center. If the other pixels in the first row fall within a critical distance from the first pixel they are assigned to that cluster. If they exceed a critical distance they become a new cluster center. Pixels in the second and subsequent rows are grouped with a previously determined cluster center if they fall with in a specified number of standard deviations. If, however, a pixel lies beyond this number it becomes a new cluster center. In this algorithm the analyst is responsible for setting the minimum cluster size, the critical distance, and the number of standard deviations used in the algorithm.

Unsupervised Classification Results

Both types of algorithms were used in order to avoid any biasing from individual algorithm deficiencies. This project created an isodata cluster with a convergence of 98%, a minimum cluster size of 40, a distance 1 of 45, a distance 2 of 34, and a threshold of 30. (See figure 1) This resulted in a thematic map with twenty-three clusters which separated the varying water depths and sediment contents particularly well. The single pass cluster created had a minimum cluster size of 40, a critical distance 1 of 45, and a critical distance 2 of 90. (See figure 2) In contrast to the water types being clearly differentiated in the isodata, the varying land types were highlighted by the eighteen clusters resulting from the single pass.