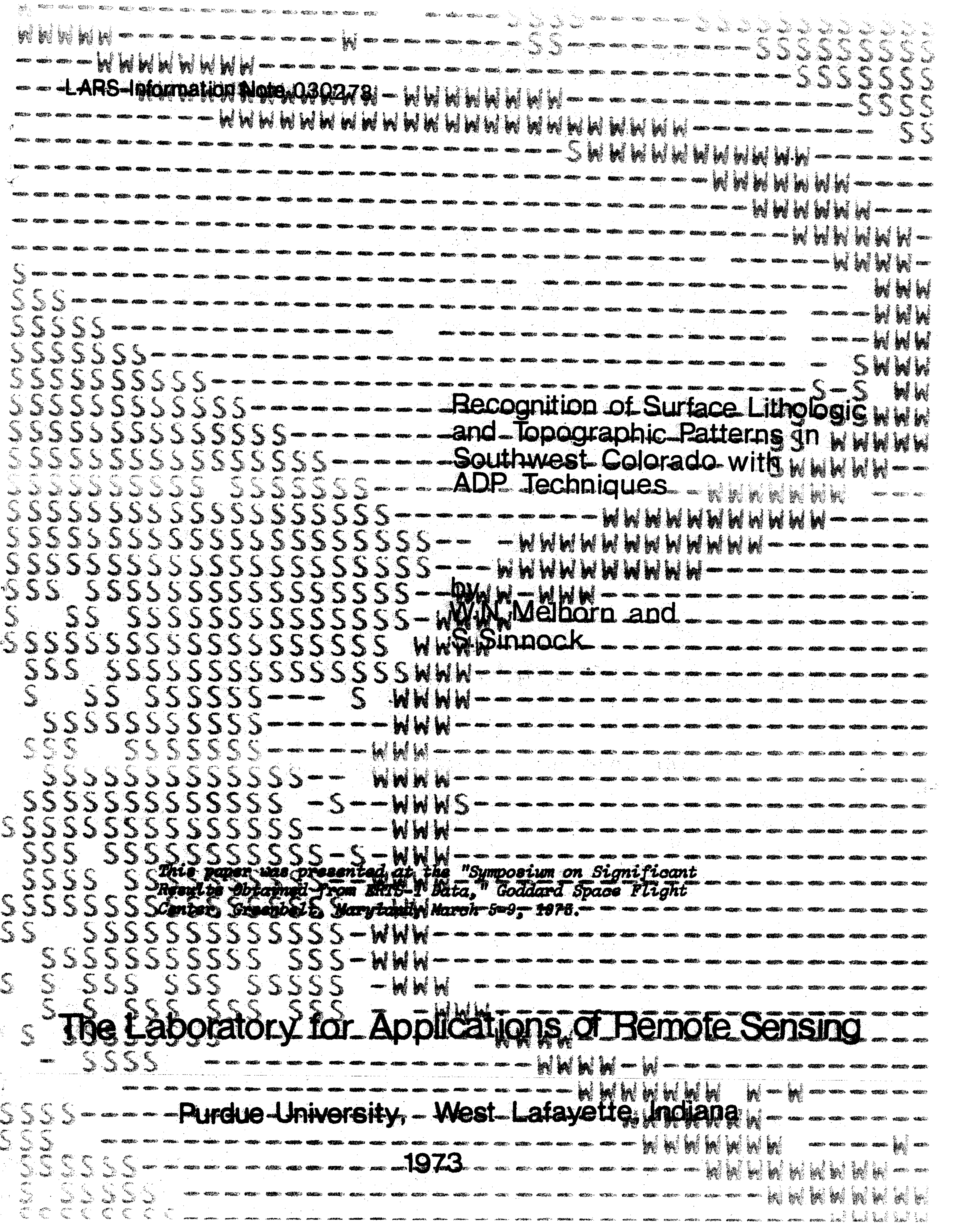

LARS Information Note 030278

Recognition of Surface Lithologic and Topographic Patterns in Southwest Colorado with ADP Techniques

by
W.N. Melhorn and
S. Sinnock

This paper was presented at the "Symposium on Significant Results Obtained from ERTS-1 Data," Goddard Space Flight Center, Greenbelt, Maryland, March 5-9, 1973.

The Laboratory for Applications of Remote Sensing

Purdue University, West Lafayette, Indiana

1973

RECOGNITION OF SURFACE LITHOLOGIC AND TOPOGRAPHIC PATTERNS IN SOUTHWEST COLORADO WITH ADP TECHNIQUES

Wilton N. Melhorn
Scott Sinnock

Laboratory for Applications of Remote Sensing
Purdue University
West Lafayette, Indiana 47907

ABSTRACT

Analysis of ERTS-1 multispectral data by automatic pattern recognition procedures is applicable toward grappling with current and future resource stresses by providing a means for refining existing geologic maps. The procedures used in the current analysis already yield encouraging results toward the eventual machine recognition of extensive surface lithologic and topographic patterns. Automatic mapping of a series of hogbacks, strike valleys, and alluvial surfaces along the northwest flank of the San Juan Basin in Colorado can be obtained by minimal man-machine interaction. The determination of causes for separable spectral signatures is dependent upon extensive correlation of micro- and macro field based ground truth observations and aircraft underflight data with the satellite data.

1. *INTRODUCTION*

The results described in this paper pertain to automatic data processing of ERTS-1 MSS data (Scene I.D. 1119-17204, November 19, 1972) for mapping physiography and geology of an area in southwestern Colorado. A block of approximately 200 mi^2 located peripherally to the San Juan Mountain Test Site, an area defined by LARS for conducting ERTS research, was chosen for computer analysis. This area, centered around Durango, Colorado was originally chosen because it appeared as a large, cloud-free block on otherwise cloud-covered data (Scene I.D. 1029-17195, August 21, 1972). Subsequent analysis was performed on the cloud-free November data set. No correlation with aircraft underflight photography or MSS imagery has been performed for this area.

The work described in this report was sponsored by the National Aeronautics and Space Administration (NASA) under Grant No. NAS 5-21880.

2. *PHYSICAL SETTING OF AREA*

The area studied near Durango ranges in altitude from 6,500 feet to about 9,000 feet above MSL. Climate is relatively moderate. Mean annual precipitation at Durango is 19.54 inches but diminishes with a decrease in elevation. Winter snow accumulation of 10 to 40 feet is not uncommon, depending on altitude. Grassland or bare soil dominates below 6,000 feet, scattered pinon and juniper occur from 6,000 to 7,000 feet, and ponderosa pine and aspen become increasingly abundant above 7,000 feet. Orchards and row crops grow in the Animas River valley. Florida Mesa southeast of Durango has been irrigated for pasture and crops since about 1900.

Geology. The San Juan Mountains are essentially an eroded, domal uplift covering about 10,000 mi^2 in southwestern Colorado. They are composed principally of volcanic rocks of Tertiary age, but older bodies of Precambrian, Paleozoic, and Mesozoic rocks are locally exposed in the mountainous core. At many places around the margin of the San Juan Mountains, Mesozoic rocks occur as a series of tilted strata that dip towards adjacent basins, and form a series of linear topographic highs and lows, or "hogback" ridges and strike valleys. The volcanic episode was succeeded during the Pleistocene by climatic conditions suitable for generation and vigorous activity of numerous, large valley glaciers that have recurred during at least 3 irregularly-spaced intervals of relatively short duration. Consequently, the geomorphic history of this rugged mountain and basin area is exceedingly but not abnormally complex. The regional erosion surface (late Tertiary) is in many places overlain by varying thicknesses of glacial till and outwash gravels. The area has been reportedly, gently upwarped in recent geologic time, so that many of the glacial deposits and associated rocks are unstable under present slope conditions. Major landslides, mudflows, and rock avalanches are not uncommon anywhere in the San Juan region. The best general accounts of the topography and geology of the region are contained in Atwood and Mather (1) and Mather (2).

Immediately east of Durango the hogbacks and strike valleys, developed respectively on hard, durable sandstones and weakly resistant shales, are particularly prominent. The slopes developed on sandstone dip southeast at about 20°. Some of the best examples of glacially alluviated benches, cut terraces, and floodplains of the entire region exist on Florida Mesa and along the valleys of the Animas and Florida rivers. Such deposits are generally highly reflective to any sensor system.

Sandstones of the hogbacks near Durango are of terrestrial origin and contain coal beds of fairly high quality and good calorific value (14,000 BTU). Mining has been sporadic, but

Zapp (3) estimated measured reserves of 42 million short tons of bituminous coal, and total recoverable reserves of 1,853 million short tons (estimating 65% recovery) within 3,000 feet of the present surface.

General stratigraphy and topographic relations of rock units in the study area are shown in Table 1.

3. *ANALYTIC PROCEDURE*

As already stated the objectives of the continuing research are to utilize LARSYS automatic pattern recognition to obtain geologic maps which refine existing maps and to produce landform simulation maps. To map geologic materials by any remote sensing technique it is necessary to assume:

1) That subsurface materials will manifest themselves as spectrally separable classes at the earth's surface. Lithologic types, sandstone, shale, etc., are often obscured with a veneer of soil, vegetation, water, and man-made features which reflect incident sunlight to the remote sensor. If the subsurface lithologies are to be mapped based on spectral information received by the sensor, it must be assumed that many spectrally separable surface features indicate subsurface lithologic variations.

2) That lithologic types are naturally segregated into a limited number of discrete compositional and textural categories which can be recognized and classified by pattern recognition procedures, either machine or human. This assumption is false, but it facilitates clustering of similar lithologies into discrete classes. Transitional features which spectrally fall between two arbitrarily chosen training classes will be classified as one of the two chosen classes. The relative spatial distribution of these "misclassified" features will reflect the natural lithologic composition (e.g., an area of sandy shale may be classified as a random distribution of feature elements of the two discrete classes, sandstone and shale).

<u>Classes Considered</u>: Based on the information provided by Zapp (1949), we divided the lithologies of the Durango area into three discrete types for analysis -- sandstone, shale, and alluvium. Sandstone is the subsurface rock type on the dip slopes of the hogback ridges; shale on the cret slopes and along the strike valleys; alluvium on the terraces and floodplains. These three material types are sufficient

There are two reasons for this confidence. First, on the automatically produced map the pattern of alternating sandstones and shales striking northeast is abruptly offset where the Florida River is superposed across the hogbacks. The cause of this offset is inferred to be movement along a fault. The rocks on the east side have been displaced to the south relative to the rocks on the west side of the fault. Zapp's map shows no fault in this area, but a zone of weakness, such as a fault, is necessary to produce the conditions required for superposition of a stream, such as the Florida River, across resistant hogbacks. It should be emphasized that the presence of the fault is inferred from stratigraphic patterns as recognized by LARSYS automatic pattern recognition rather than from visual recognition of a surface lineament represented on non-classified gray scale or color imagery.

The second reason for confidence is the very high correlation between the machine map and Atwood's (1932) map of relict erosion surfaces. Atwood shows a remnant of the Tertiary erosion surface on the dip slope of the Pictured Cliff Sandstone just east of Durango. The boundaries of this "ancient peneplain" remnant are surprisingly similar to the boundaries of the Pictured Cliff dip slope as outlined by the computer. These two reasons, the first based on geologic inference, the second on correlation with previously mapped ground truth, indicate a high degree of accuracy and applicability of the experimental map for geologic purposes.

Figure 3. Physiography of the Second Test Area, Located 30 Miles East of Durango Training Area. Approximate Scale 1:150,000.

Figure 4. Geologic Map of the Second Test Area.

To test the applicability of the classification scheme to regional areas, an approximate 200 mi^2 area centered 35 miles northeast of Durango was classified by using the same statistics calculated on the experimental training fields located two to five miles east of Durango. This new test area was chosen because: 1) the lithologies were similar to those of the first study area, 2) the elevations and presumably the altitude dependent vegetative cover types were different, and, 3) the reflective sun angle on the hogbacks was different. The display images of this area are presented in Figures 3 and 4. The physiographic and geologic maps of the test region "make sense" geologically, but no ground truth is available to test our results. It is apparent that extensive field based micro- and macro-ground truth observations and aircraft underflight data of this second area are needed before any definitive statement concerning the reliability and accuracy of the machine produced maps can be demonstrated.

5. *APPLICATION CONSIDERATIONS*

In our opinion, the experimental method outlined has several applications for improving geologic mapping capabilities. The degree of improvement depends on: 1) the character of the terrain, 2) the areal distribution of surface features, and 3) the purpose of the maps required for a particular project. Additionally:

1) Multiple use of the same classification statistics can be employed for producing alternate map types (e.g., physiographic and geologic maps).
2) Multiple map scales, ranging from 1:24,000 to 1:1,000,000, are available to users of unaltered LARSYS displays.
3) A high degree of accuracy is obtained.
4) Statistics calculated from a "type section" of limited areal extent can be applied regionally to obtain classification maps of broad areas.
5) Compact storage in magnetic data tape libraries is possible. (The Durango study area statistics necessary for display of the maps presented in this report are stored on about 30 feet of magnetic tape.)

7. *REFERENCES CITED*

1. Atwood, W.W. and K.F. Mather. 1932. *Physiography and Quaternary Geology of the San Juan Mountains, Colorado:* U.S. Geological Survey, Prof. Paper 166. 176 pp.

2. Mather, K.F. 1957. *Geomorphology of the San Juan Mountains: New Mexico Geological Society Guidebook.* 8th Field Conference, Southwestern San Juan Mountains, Colorado. pp. 102-108.

3. Zapp, A.D. 1949. *Geology and Coal Resources of the Durango Area, La Plata and Montezuma Counties, Colorado:* U.S. Geological Survey, Oil and Gas Investigations Preliminary Map 109, 2 sheets.