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Title: Geologic and Mineral and Water Resources Investigations in Western Colorado (Proposal 026)

(GSFC Principal Investigator Identification No. UN 209)

(E73-10422) GEOLOGIC AND MINERAL AND WATER RESOURCES INVESTIGATIONS IN WESTERN COLORADO Progress Report, 1 Feb. - 31 Mar. 1973 (Colorado School of Mines) 8 p HC $3.00 CSCL 08G G3/13 N73-20383 Unclas 00422

INTRODUCTION

The primary objective of the Colorado School of Mines ERTS-1 Program is to analyze ERTS-1 data for identification and discrimination of geological and hydrological phenomena in central and western Colorado. To facilitate the achievement of this objective, the research has been subdivided into the following tasks:

Task I. Analyze ERTS-1 data for identification and discrimination of:
- A. lithology and surface composition
- B. geologic structure
- C. geomorphic phenomena
- D. mineral resources
- E. water resources
- F. volcanic phenomena

Task II. Determine the atmospheric affects on remote sensor data.

Task III. Investigate and evaluate:
- A. the RBV and MSS data for task I, A through F
- B. processing and enhancement techniques as applied to ERTS-1 data

Task IV. Educate graduate students and give experience to research personnel in the use of satellite remote sensor data.

Task V. Submission of a final report (Type III) which will discuss in depth the history of the overall project and all significant scientific and technical theories, procedures, techniques, equipment, tests and project results.

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TOPICAL RESULTS

During the report period investigators have done detailed interpretation, analysis and evaluation of ERTS-1 data for various areas in central and western Colorado. The first areas interpreted were areas in which the investigators were familiar. Ground control for the interpretation and analysis was provided by high- and low-altitude photography, field data obtained during the summer of 1972, and previously existing geologic maps and publications.

Lithology and Surface Composition

Analysis of 9-inch positive transparencies of ERTS-1 imagery of central and western Colorado shows an encouraging success in locally discriminating between recognized sedimentary formations within the thick sedimentary sequence. The discriminations are generally possible because of tonal changes on the imagery representing differences in spectral reflectance of the rocks themselves or residual soils developed on them. Topographic relief caused by differential erosion of resistant/non-resistant beds is the second most important factor in lithologic discrimination, Selective vegetation growth occasionally helps in lithologic discrimination, but in general, vegetative cover is a hinderence.

Lithologic discrimination of rock units within both the Precambrian crystalline and Tertiary volcanic terrains of the state has met with much less success. These rock types are, for the most part, restricted to the more mountainous portions of the state where climatic conditions are favorable for heavy timber growth. The rocks within these terrains have very low spectral contrasts which makes discrimination difficult even where not covered by timber. It is generally true, however, that mountainous areas covered by timber are underlain by Precambrian crystalline or or Tertiary volcanic rocks rather than sedimentary strata -- a crude form of lithologic discrimination.

Geologic Structures

ERTS-1 imagery contains a wealth of structural geologic information.

Large fold structures -- uplifts and basins -- can be easily defined by 1) topographic expression, 2) gross distribution of rock types, and 3) dips of sedimentary strata. Local folding along the edges of the major uplifts and within sedimentary basins can be detected where the outcrop pattern of the sedimentary strata is enhanced by spectral contrasts between adjacent formations; the smaller folds are also commonly reflected in topography.

ERTS-1 imagery provides information on the nature and domains of regional fracture systems as a result of interpretation and analysis of ERTS-1 lineament data. The lineaments are defined by vegetation alignments and topographic expression, primarily the latter. Comparison of ERTS images from August 1972 and January 1973 indicates that sun elevation angle is an extremely important consideration in the application of ERTS imagery to regional fracture analysis. The low angle solar illumination in the January imagery (27°) produced dramatic topographic shadowing thereby enhancing topographically-expressed structures. Snow cover in the January scene improved the contrast between shadows and background. Many cases have been observed where structural and lithologic information not recorded in the high sun-angle August imagery (59°) is present on the January imagery.

The abundance of the linear data capable of being extracted from ERTS-1 images prompted use of statistical analysis techniques for determining the location and distribution of significant trends. Linear data are plotted on overlays on the 9-inch positive transparencies. Each scene is divided into 16 equal subareas and the number and azimuths of all linears are measured for each subarea. The quantitative data are punched on computer cards and submitted to analysis by computer program. The program computes a strike frequency analysis and prints a strike frequency graph, determines frequency maxima, and calculates statistical confidence values for the maxima. Significant trends are selected from the computer analysis.

To test the analysis technique, the linear data from the area covered by ERTS-1 images 1154-17143-4,5,6,7 were analyzed. Eight statistically significant trends were found for the whole area. Most of these trends are parallel to known tectonic strikes and regional fracture patterns.

Geomorphic Phenomena

Geomorphic features are enhanced and more easily interpreted on simulated color-IR composites. A striking example of this enhancement is seen by comparing B/W transparencies and the color-IR composite of the Canon City area. The hogbacks (Paleozoic section) north and northeast of Canon City are vividly depicted on the color composite but are relatively vague on the B/W transparencies. The reason for this difference appears to be due to both greater tonal contrast and color contrast between the hogbacks and the surrounding area on the composite image. The color-IR composite does an excellent job of discriminating general vegetation type and variations. This ability results in high detectability and enhancement of drainage systems due to characteristic variation associated with slope and moisture.

Atmospheric Effects

Atmospheric measurements included spectral, total, diffuse, and direct radiation at two locations. A Bendix Model 100 Radiant Power Measuring Instrument (RPMI) was used at the Eleven Mile Reservoir site and an ISCO spectral radiometer was used at the Granite Hills site.

On 22 February 1973 the Bendix instrument was taken to Loveland Pass (elevation 3,655 m) to test performance consistency by comparison with data collected on 16 February. Considerable variation in Band 4 (.8-1.1 micron) data collected 16 February was attributed to water vapor absorption and it was expected that the higher elevation of the Loveland Pass site would minimize this effect. Data were collected during the early morning, but jet contrails generated significant cirrus clouds and invalidated late morning data. The remainder of the day was spent searching for a suitable high altitude measurement site that was not located beneath a jet route. An excellent site was selected about 8 miles WNW of Fairplay at 3,551 m (11,650 ft) elevation. A similar trip was made to the Fairplay site on 27 February 1973. High cirrus clouds (natural) prevented making valid measurements. The site was photographed and accurately located on the Mount Lincoln quadrangle.

In late April-early May Mr. R. L. Hulstrom (Martin Marietta Corp. - Denver Division) will present a paper to the Pan American Institute of Geography and History, Republic of Panama, on the results of studies of the effects of the atmosphere on remote sensing performed under this contract. An abstract of the paper is given below:

ATMOSPHERIC MEASUREMENTS AND ANALYSES
IN SUPPORT OF REMOTE SENSING

by

R. L. Hulstrom

ABSTRACT

The remote sensing of objects on the earth's surface from aircraft and spacecraft platforms is hampered by the intervening atmosphere. The intervening atmosphere affects remote sensing in many ways. This paper will consider the solar radiation-reflected region of the spectrum .3 to 3.0 micrometers (μm). If the ground feature is being remotely sensed by recording the solar radiation reflected from its surface, the atmosphere will play an important role in this type of remote sensing because it affects both the incoming solar radiation that irradiates the feature and it affects the reflected "signature" of the feature as it travels up through the atmosphere to the aircraft or spacecraft. The major atmospheric effects are: (1) attenuation of the direct solar beam by molecular scattering, aerosol scattering, and selective absorption by atmospheric constituents such as O_2, O_3, H_2O, and CO_2; (2) a downward sky radiation onto the ground feature, created by molecular and aerosol

scattering of sunlight; (3) attenuation of the radiation reflected from the ground feature as it traverses the atmosphere, by molecular and aerosol scattering, and absorption (similar to the effects on the direct, incoming solar beam, and (4) the backscattering of radiation into the remote sensor which can be though of as "noise." The resultant impact of these effects is that of causing inaccurate classification/recognition of ground features by using the spectral "signature" approaches. Such approaches of automatic, computer recognition and mapping using multispectral scanner/ spectrometer data generated by aircraft, ERTS, and EREP are widely used by the remote sensing community. Because of the greater ground area covered, the impact of atmospheric effects on satellite remote sensing is generally more severe than aircraft remote sensing. However, atmospheric effects should be considered and corrected for in both cases.

This paper briefly describes the basic concepts of atmospheric transmission and resultant effects on the remote sensing process. The major emphasis is on the appropriate atmospheric field measurements, instrumentation, and analyses of field measurements that should be considered in order to allow subsequent corrections for atmospheric effects to be made. The measurements, techniques, methods, instrumentation, and analyses will be discussed in detail with specific examples shown. The examples are taken from the ongoing research activity in central Colorado which involves aircraft, ERTS, and EREP remote sensing projects. Remote sensing projects in this area include the Colorado School of Mines, Colorado State University, Martin Marietta Aerospace, University of Michigan, and the United States Geologic Survey. In support of these projects a complete atmospheric corrective measurement program has been applied to the area and will continue for ERTS and EREP applications.

Processing and Enhancement Techniques

Good success has been obtained in making color composites from 9" x 9" B/W transparencies using colored Diazo film. The Clark systems multispectral projector Model 5005 is used to establish the band/color/

intensity combinations which seem to best enhance the features of interest. Many combinations can be examined rapidly with this system although the resulting format (image as projected onto a ground glass screen) is not suitable for detailed analysis. The best results using the colored Diazo film has been in simulating color-IR images. The initial relative color intensities to be used with each band was established with the multispectral projector. The exposure of the Diazo film is controlled, within limits, by regulating the operating speed of the Diazo machine. First generation composites were made using relatively thin Diazo film exposures that appeared to have the most tonal variations. However, it was found that superior renditions result from using relatively dense exposures. Most of the composites used either Band 6 or Band 7 but a very good composite was constructed using both infrared bands (MSS 6 + 7). Trouble was encountered in making a composite for the ERTS track over the Gunnison area for use in stereo viewing. The B/W transparencies were quite dense resulting in very dense exposures. Adjustment of the Diazo machine speed would not compensate adequately for the dense transparencies.

Preliminary studies of the color additive viewing technique using the I^2S viewing system indicate that ERTS-1 image interpretability can be improved. To date, only qualitative evaluations of the technique have been made for color composites projected on the viewing system screen. Future detailed evaluations will be made on photographic prints of the screen.

Ground Support During Satellite Overpasses

Two field crews were on station during the 16 February 1973 ERTS-1 overpass. In addition to the atmospheric measurements previously mentioned, spectral reflectance measurements were made of the Pikes Peak Granite with the ISCO spectral radiometer. Additional spectral reflectance data of the Pikes Peak Granite were obtained with the Bendix M-100 instrument about four hours after the overpass. Snow reflectance was measured in the vicinity of Eleven Mile Reservoir with the Bendix instrument but cold temperatures prevented proper ISCO operation. Both the 15th and 16th of February were cloud free and excellent ERTS data can be expected for these overpasses.

PROJECT STATUS

Progress of ERTS-1 satellite and support data analysis, interpretation, and evaluation is proceeding along a productive course and should be completed on schedule. Current funding appears to be adequate for meeting the stated objectives of the CSM/ERTS-1 project.

NEXT REPORTING PERIOD

During the next reporting period ERTS-1 satellite and support data will continue to be analyzed, interpreted, and evaluated. Work with the different methods of producing color composites of ERTS-1 imagery will be continued with the goal of producing stereo pairs for geologic interpretation. Video image processing (color coded density slicing) of ERTS-1 imagery will be studied for potential applications to geologic analysis.

The effect of angle of solar illumination on the geologic utility of ERTS-1 imagery will be investigated in more detail; the contribution of snow cover to the shadowing enhancement will be studied.

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