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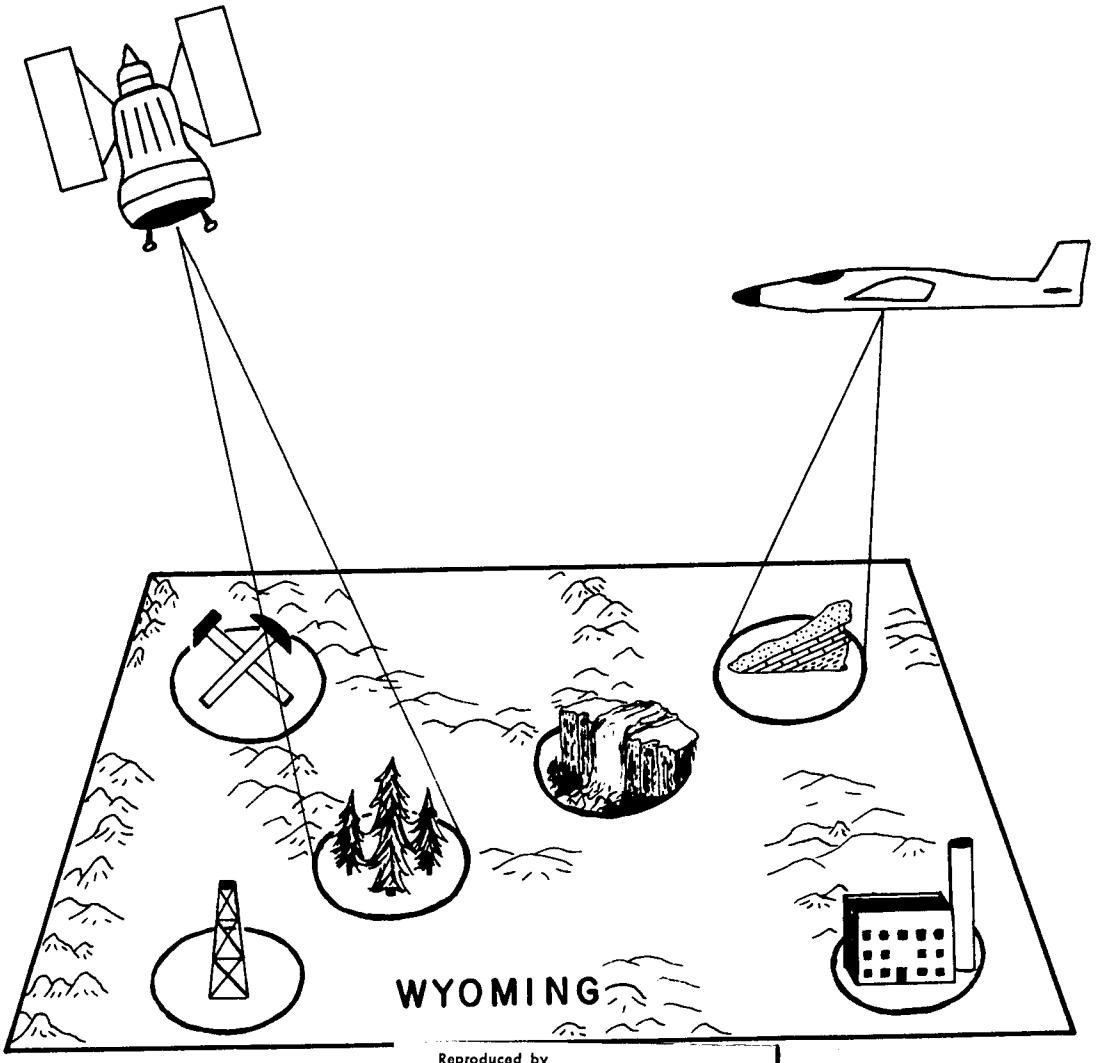

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ANALYSIS OF ERTS-1 IMAGERY AND ITS APPLICATION TO EVALUATION OF WYOMING'S NATURAL RESOURCES

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16. Abstract

The multidisciplinary ERTS-1 investigation at the University of Wyoming progressed without major problems during the January-June, 1973, report period. Several of the program goals were attained as experiments begun in late 1972 were completed. These first-completed experiments demonstrated the potential of the ERTS data for mapping geologic structure, stratigraphy, and morphology and for land-use planning applications. Other experiments that are still underway are designed to test this potential in various situations and in broad-scale applications. Still other studies testing the utility of ERTS data for vegetation and hydrologic applications are in progress.

The overall quality and resolution of the ERTS imagery has proven better than anticipated. Consequently, we expect to accomplish all major contract objectives, and have, during the course of our investigations, discovered several unanticipated applications of the ERTS-1 data.

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PREFACE

This report summarizes the progress of the University of Wyoming ERTS-1 study for the January-June investigative period. During this period the investigators had their first opportunity to check many of the image interpretations that had been compiled during the first nine months of the study. The resulting confirmations of many of the interpretations have brought us considerably closer to the realization of most of the investigative goals. They have also focused attention on other problems which may be approached through the use of ERTS-1 imagery. As our study of the ERTS images continues we find some unanticipated applications which demand our immediate attention while other exciting aspects are set aside for study after the primary investigative objectives have been met.

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INTRODUCTION

Objectives of the Wyoming ERTS-1 investigation include the application of satellite imagery to geologic, hydrologic, agricultural, botanical, and land-use studies. Among the specific geologic objectives are: 1) discrimination and mapping of various geologic units including sedimentary, igneous and metamorphic types; 2) recognition and mapping of structural elements, such as folds, faults, lineations, and major joint systems; 3) identification of facies changes and color anomalies in rocks and soils; and 4) determination of regional relationships between these geologic features. The ultimate goal is a better understanding of the total geologic picture and a greater capability to locate and/or inventory natural resources controlled by their geologic framework.

Hydrologic applications of the ERTS-1 imagery in Wyoming are largely concerned with estimation of water reserved as snow-pack, reservoir- and lake-stored water, and near surface soil moisture, but the program also has as one of its objectives the monitoring of transient or locally significant hydrologic features such as saline lakes, alkali accumulations, and pollution and sedimentation in major water bodies.

Agricultural and botanical investigations within the framework of the Wyoming ERTS program are intended to establish the usefulness of ERTS imagery for mapping and observing growth conditions in both natural and cultivated vegetation. This information can then be applied to assessment of natural and agricultural resources and to planning for optimum resource use.

Evaluations of ERTS-1 imagery as an aid in land-use planning are, of course, mostly dependent upon the successful application of the imagery to mapping geology, vegetation, and cultural features. Thus, land-use (both actual and potential) information gained from the ERTS imagery might be considered a final product to be derived from the combination of the geologic,

hydrologic, vegetative, and cultural components.

Investigative tasks that have been completed in the last six months and others that are now in progress are summarized in this report and evaluated relative to these program objectives.

INVESTIGATION PROGRESS AND SIGNIFICANT RESULTS

Significant results of the Wyoming ERTS-1 investigation during the first semi-annual report period (July-December, 1972) included: 1) successful segregation of Precambrian metasedimentary/metavolcanic rocks from igneous rocks, 2) discovery of iron formation within the metasedimentary sequence, 3) mapping of previously unreported tectonic elements of major significance, 4) successful mapping of large-scale fracture systems of the Wind River Mountains, 5) successful distinction of some metamorphic, igneous and sedimentary lithologies by color-additive viewing, 6) mapping of large-scale glacial features, and 7) development of techniques for mapping small urban areas.

Several of the studies which produced these significant results were nearing completion as the first semi-annual report was prepared. These studies have since been completed and the results detailed in special reports (Houston, 1973; Breckenridge and others, 1973; and Breckenridge, 1973). Other studies completed during the January-June period included investigations of linear features observed on ERTS imagery of the Laramie Range of southeastern Wyoming and the Bighorn Mountains of north-central Wyoming. This work, performed under the direction of Dr. D. L. Blackstone, Jr., involved a comparison of the dominant directional trends of the linear features to the major axial trends of Laramide folds which occur in the basins flanking each of these mountain ranges. The comparison provided a test of possible relationships between joint- and fracture systems in the Precambrian crystalline cores of the mountains and the later basin folding. In the case of the Laramie Range and folds in the

nearby Laramie Basin a striking correlation was observed between the azimuths of the photo-linear features and the fold axis indicating basement control of Laramide folding by older zones of weakness (Blackstone, 1973a). However a similar study in the Bighorn-Pryor Mountain area indicated no relationship between the folds of the Bighorn Basin and the joints and fractures of the adjacent uplift (Blackstone, 1973b). The results of these studies have significant implications with regard to the structure and geologic history of Wyoming and present plans include similar applications of the ERTS-1 imagery to the study of other geologically complex areas of Wyoming where such relationships may be important.

Other studies presently in progress as components of the Wyoming ERTS-1 program include: 1) an attempt to apply the ERTS imagery to broad-scale geologic mapping of a large, heterogeneous region of central Wyoming; 2) a study in which a combined geologic, physiographic, and land-use map is being prepared from ERTS image interpretations; 3) a detailed study testing the utility of ERTS data for rangeland mapping; 4) an attempt to map snow cover and estimate available water in a central Wyoming drainage basin; 5) a detailed investigation of the use of ERTS-1 imagery for mapping soils in an agricultural region near Riverton, Wyoming; 6) the application of ERTS-1 imagery to mapping of volcanic lithologies and structure in the Absaroka volcanic field of northwestern Wyoming; and 7) the use of ERTS-1 imagery for defining major vegetative communities in the Laramie Mountains and Laramie Basin.

Dr. R. S. Houston has constructed a broad-scale geologic map from interpretations of the ERTS imagery for the central Wyoming area corresponding to the Army Map Service (AMS) Arminto 2-degree topographic map. The 1:250,000-scale geologic map compiled from the image interpretations is color-keyed to

the hue and brightness values of the map units seen on the imagery. Consequently, the map patterns can be compared directly to color patterns on the composite ERTS images which represent lithologies of distinctive hue and brightness. The distinguishable units are assigned map-unit status regardless of their official stratigraphic classification. Field checking is presently underway to establish the validity of correlations between image patterns and lithologies, and several very strong and consistent patterns have been defined. For example, red-bed and shale sequences are characteristically displayed in shades of yellow and gray, respectively, on the color-infrared composite imagery. Consistent correlation allows reliable identification of these particular lithologies from the image interpretation. Other image patterns may prove similarly diagnostic and may allow identification of specific lithologies and their associated sequences from ERTS image interpretations. Another important facet of this work is the comparison of the image-derived map with the 1:500,000 scale Wyoming Geologic Map and with detailed geologic maps available for portions of the area. The image-derived map (1:250,000) lacks much of the detail available from the detailed maps but should reveal some significant features not seen on the 1:500,000 state map. Thus, the interpretation provides additional geologic information in areas not mapped in detail. Specific results of this study will be presented in a forthcoming report by Dr. Houston.

Dr. R. W. Marrs is presently conducting a geologic, physiographic, and land-use mapping program in the Rawlins area of south-central Wyoming. The 3000-square-mile study area includes large portions of the Washakie and Hanna Basins and the northern parts of the Sierra Madre and Medicine Bow Mountains. Physiographic and cultural features detected on the ERTS images are interpreted

in various contexts to yield a suite of maps displaying broad-scale information about agriculture, soils, slopes, natural vegetation, surface water and geology. A color coding scheme similar to that devised by Dr. Houston is being employed in order to expedite correlation of similar features and areas across the region and to permit definition of those features that prove significant and show a characteristic response on the imagery.

This program is yet in its initial stages and will require additional imagery of the Medicine Bow Mountains and Sierra Madre for which we have not yet received cloud-free and snow-free ERTS imagery. It is anticipated that this imagery will soon be available and that the entire study area will be mapped.

Field checks of the already completed maps of the northwest portions of the study area are currently underway with results thus far being quite encouraging. Maps of the folded sedimentary rocks in the vicinity of Rawlins have been found quite accurate and subtle distinctions in the relatively featureless rangeland west of Rawlins have proven significant with regard to both the geology and vegetation pattern.

Mr. Robert Gordon is conducting a detailed study in the Baggs, Wyoming area to determine the usefulness of high altitude imagery for mapping rangeland vegetation types and to estimate the above-ground green biomass present in specific areas of the Baggs study site.

Field studies are presently being conducted and are progressing favorably. Maps of vegetation types interpreted from ERTS imagery have been partially field checked and have aided in the selection of study plots and transects. In addition to the regional interpretations of the vegetation types, more detailed vegetation maps are being compiled from ground studies and from intermediate-altitude aircraft imagery.

Ten permanent reflectance plots were chosen in each of two major study areas selected from the ERTS imagery. During each ERTS overpass photographs are obtained for 25 randomly located 4-x 5-ft. plots. Estimates are made of shrub, grass and forb, and litter for each of the 25 plots using a double sampling technique. These estimates are checked by taking six sub-samples, which are oven-dried and weighed to provide a correction factor. Soil moisture samples are also processed at this time.

Biomass and reflectance measurements are taken from a new set of plots for each satellite pass sequence. This allows sampling of about 150 plots per test area during one growing season.

A strong correlation may exist between variations in ERTS-band reflectance values and above-ground green biomass. If this correlation can be firmly established, it should be possible to use the ERTS data to estimate the green biomass present in a range area.

A cooperative effort between University of Wyoming investigators and investigators at the Goddard Space Flight Center is underway to apply the ERTS imagery to estimating available water in snow-pack and reservoir storage. The Bull Lake drainage basin on the eastern flank of the Wind River Mountains has been selected as a test area. A particularly good sequence of useable ERTS images is available for this area and additional interest is provided by a current storage of water which is of considerable concern to the area residents.

In this study the ERTS imagery is employed in mapping the snow-covered area and estimating the water content of the snow by combining ERTS image area and density measurements with snow-depth and moisture readings gathered routinely by personnel of the U. S. Soil Conservation Service.

A second aspect of this study employs the ERTS data in monitoring the accumulation and depletion of reservoir water. We anticipate that the volume of water retained in reservoirs can be determined by combining the surface-area measurement with a mathematical function representing an empirical area/volume conversion. The empirical relationship can be predetermined by comparing existing surface-area measurements and stored water figures.

As yet, we have progressed only through the initial stages of this study and have encountered significant difficulty in the mapping of snow-cover in heavily forested areas and in making adequate depth and moisture content estimates. However, we feel that these difficulties can be dealt with.

An investigation of the utility of ERTS-1 imagery for general vegetative mapping was initiated in the autumn of 1972 by Mr. Francis Redfern of the University of Wyoming Botany Department. Mr. Redfern has since left the University, but he completed the image analysis and prepared a tentative report of his findings before he left. We elected to field-check the results of that study before submitting the summary of that work. The field-check has now been completed and the summary report is in preparation.

A study area near Riverton has been chosen for evaluating the usefulness of ERTS-1 in delineating soil types in that region. The Riverton area has recently been mapped in detail on a large-scale photographic base by the Soil Conservation Service. NASA aircraft missions 184 and 213 provide excellent low-level coverage of most of the Riverton study area. The aircraft data allow positive correlation of photographic contrasts with the available soils maps and provide a ready means of confirming the ERTS image interpretations with a minimum of field checking. A previous attempt to map soils in the Powder River Basin (Breckenridge, Marrs and Murphy, 1973) was successful on a broad scale.

In the Powder River Basin the soil types were mapped using the substrata to anticipate the weathering products and thus the related soil type. The Riverton area has better developed soils and extensive agricultural development. The present soil classification (the 7th Approximation, U.S.D.A.) is not directly applicable to remotely sensed data. However, a number of pedologic factors can often be recognized; soil moisture, vegetation, color, slope, elevation, etc. Spectral measurements have been made on several of the important soil units in order to better define the spectral variations observed on the ERTS imagery and to aid in establishing the soil properties that control these variations.

A study to evaluate the usefulness of ERTS imagery in mapping volcanic lithologies and structure involves a geologically complex test site in the Absaroka volcanic field. Preliminary maps from U-2, color-infrared imagery indicate a correlation between dikes, fracture zones, and mineralized areas. Final assessment of this relationship is presently underway as field checks are made. If the correlation is confirmed, a regional map prepared from interpretations of ERTS and high-altitude aircraft imagery should prove very valuable as a guide to detailed mineral exploration in that area.

CONFORMANCE WITH WORK SCHEDULE

Phase III of the Wyoming ERTS-1 investigation (continuing data analysis) remains on schedule while encouraging results from several field checks suggest that the accuracy of maps prepared from ERTS image interpretations is somewhat better than expected. Consequently, we are anticipating successful completion of all contract objectives within the proposed time period. We have recently received early-spring images in which the snow-line has receded sufficiently to allow their use in vegetative-mapping experiments that require

seasonal data. However, these experiments cannot be completed until late autumn, after a full annual cycle has been studied from ERTS-1 data.

PERSONNEL

Several changes in investigative personnel have occurred during the January-June, 1973 report period. Most significantly, Mr. Roy Breckenridge, who has been a major contributor to the Wyoming program since July, 1972, has completed his degree work and accepted a position with the Wyoming Geological Survey. He is now preparing reports on his recently completed work with the ERTS imagery of the Absaroka volcanic field and the Riverton agricultural area.

Two graduate research assistants and a clerical/technical assistant have been added to the program. Mr. Mike Evans, a graduate student in botany, is presently engaged in completing the work begun by Mr. Francis Redfern who recently left the program. Mr. Evans will continue with other experiments in botanical applications of ERTS data after completion of the Laramie Basin study.

Mr. Kenneth Kolm has recently come to the Geology Graduate School of the University of Wyoming and will join the ERTS-1 investigative team in studying environmental geologic applications of the ERTS data. Mr. Kolm is presently compiling an ERTS interpretation map of sand dunes of Wyoming and will attempt to ascertain the interrelationships between the dunes and the hydrologic, vegetative, and cultural patterns of the area.

Miss Sue Baskett has joined the Wyoming team as clerical and technical assistant. Miss Baskett's chief responsibilities are to maintain project records, and correspondence and data files, and to provide technical assistance in the operation of field and laboratory equipment.

With the addition of the new people, the Wyoming team has maintained a fairly well-rounded investigative staff. Mr. Breckenridge's departure from the program has temporarily left us without a specialist in geomorphology. However, we have made a commitment to add still another graduate research assistant (specializing in geomorphology) to the program in September, 1973.

EXPLANATION OF PROBLEMS

The only continuing problem in the Wyoming ERTS-1 investigation has been lack of snow-free and cloud-free imagery for some prime test areas; particularly the region of the Medicine Bow Mountains and Sierra Madre. However, the latest imagery that we have received (May 18, 1973) has somewhat alleviated this problem. The May 18th imagery is cloud-free and only the mountains are snow-covered, allowing us to begin long-delayed studies in the low-altitude portions of this critical area.

In previous reports we have discussed the difficulty encountered in obtaining retrospectively ordered image products. This problem still remains. In November and December, 1972, we requested images from an ERTS pass sequence from September 7-12 which had not been included in our original standing order. We also requested several images that had been omitted from various early data shipments. Among the requested images are some of the best images obtained of some parts of Wyoming. Still, with periodic inquiries about these data, we have had no success in getting the needed images.

More recently, we have noted still another problem with one image product: the 9x9 inch prints. We have compared the early "undodged" prints with the newer "dodged" product and find distinct advantages and disadvantages with each. In general, the dodged prints retain better detail in consistently light or consistently dark areas than did the undodged prints. At the same time contrasts appear to be reduced by dodging areas of intermediate gray tones while

areas of sharp high-contrast boundaries show bright halos around dark objects. This latter feature is particularly significant around water bodies which are displayed in very dark tones on most ERTS bands.

ADEQUACY OF FUNDS

Expenditures continued within budgeted limits for the January-June, 1973 report period. In fact, a slight surplus has developed in the categories of part-time labor and travel. The accumulation of budgeted labor funds resulted from the delay in locating a suitable graduate assistant in plant science and from Mr. Redfern's departure from the program. However, the contract objectives will require additonal effort in botany and plant science and the accumulated funds will be needed to support this effort. In order to accomplish the contract objectives, we have employed a part-time technical assistant to handle routine maintenance, equipment operation and data handling, thus allowing the investigators more research time.

The apparent surplus in travel funds is a result of the delayed launch and data dissemination experienced last summer. These delays forced most of the investigators to postpone field work scheduled for summer, 1972. This work remains to be done and has been added to the work load for summer, 1973. Consequently, a great deal more work than originally planned is scheduled for this summer and the cost will be correspondingly increased.

PLANNED WORK FOR NEXT REPORT PERIOD

Work planned for the next report period (July-December, 1973) includes the completion of ERTS data analysis and preparation of the final report. All contract objectives should be met in this investigative period.

In the more immediate future we anticipate completion of the work with the volcanic rocks of the Absaroka area, the soils of the Riverton area, and the vegetation of the Laramie Basin. Special reports on each of these studies should be completed by the end of August. Work will also continue on each of the studies summarized in the "Investigation Progress" section of this report. The bulk of the effort in the immediate future will be spent in field checking already completed ERTS-1 image interpretations or in gathering field spectral data and samples to better define observed differences and similarities of observed features.

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