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REMOTE SENSING
LABORATORY

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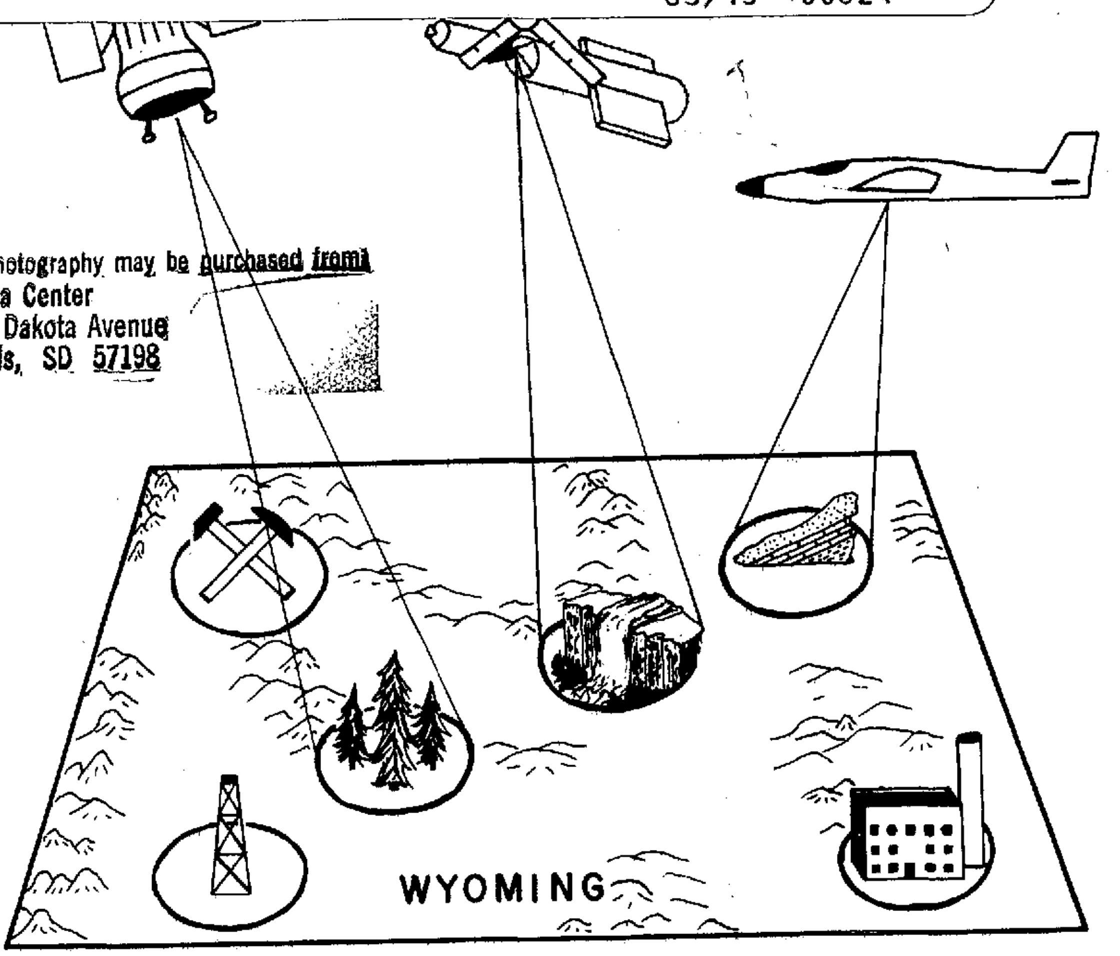

PROGRESS REPORT 3 - - MULTIDSCIPLINARY

STUDY OF WYOMING TEST SITES

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16. Abstract

Natural resources applications of EREP photographic data have been investigated as a part of the Wyoming multidisciplinary study. These include analysis of drainage patterns and regional linear features, identification of altered and mineralized areas, general structural and lithologic mapping, and various forms of topical mapping. Crops, mines, pediments, water impoundments, and baked shales have been successfully mapped using the EREP photography. Image data with the resolution of the EREP S-190 photography provides synoptic coverage necessary for regional applications and detail intermediates between aerial photography and ERTS satellite imagery.

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Figure 2. Technical Report Standard Title Page

CONTRACT OBJECTIVES

Objectives of the Wyoming EREP investigation include research into applications of EREP data to hydrologic, biologic, geologic, geothermal, and land-use problems. Because most data users are limited to visual analysis of satellite data, major emphasis is placed on applications which can be accomplished through visual techniques. Enhancement procedures are restricted, as much as possible, to techniques which employ simple and relatively inexpensive equipment. More sophisticated laboratory analyses and computer techniques are employed for reference determinations and as special-purpose enhancement procedures.

OVERALL STATUS

The initial phases of the Wyoming EREP investigation have lagged behind the investigative schedule set forth in the "Milestone Plan" (Marrs, 1973). This delay is largely a result of delayed launch and belated receipt of EREP data. Time schedules for the various individual studies have been postponed in accordance with the starting delays so that investigative expenditures could be reduced to a minimum until adequate data were made available. Currently both investigative progress and expenditures are approximately four months behind schedule. We anticipate that all research objectives will be realized with no increase in budgeted spending but that completion dates for some studies may reflect starting delays.

Currently available data include S-190A and S-190B photography obtained during Skylab missions 2 and 3. Useable photography covers approximately 50% of Wyoming (fig. 1). This coverage is adequate for three of the five prime study areas identified within the Wyoming test site. Studies to be undertaken in the areas not covered must be relocated or be completed using partial

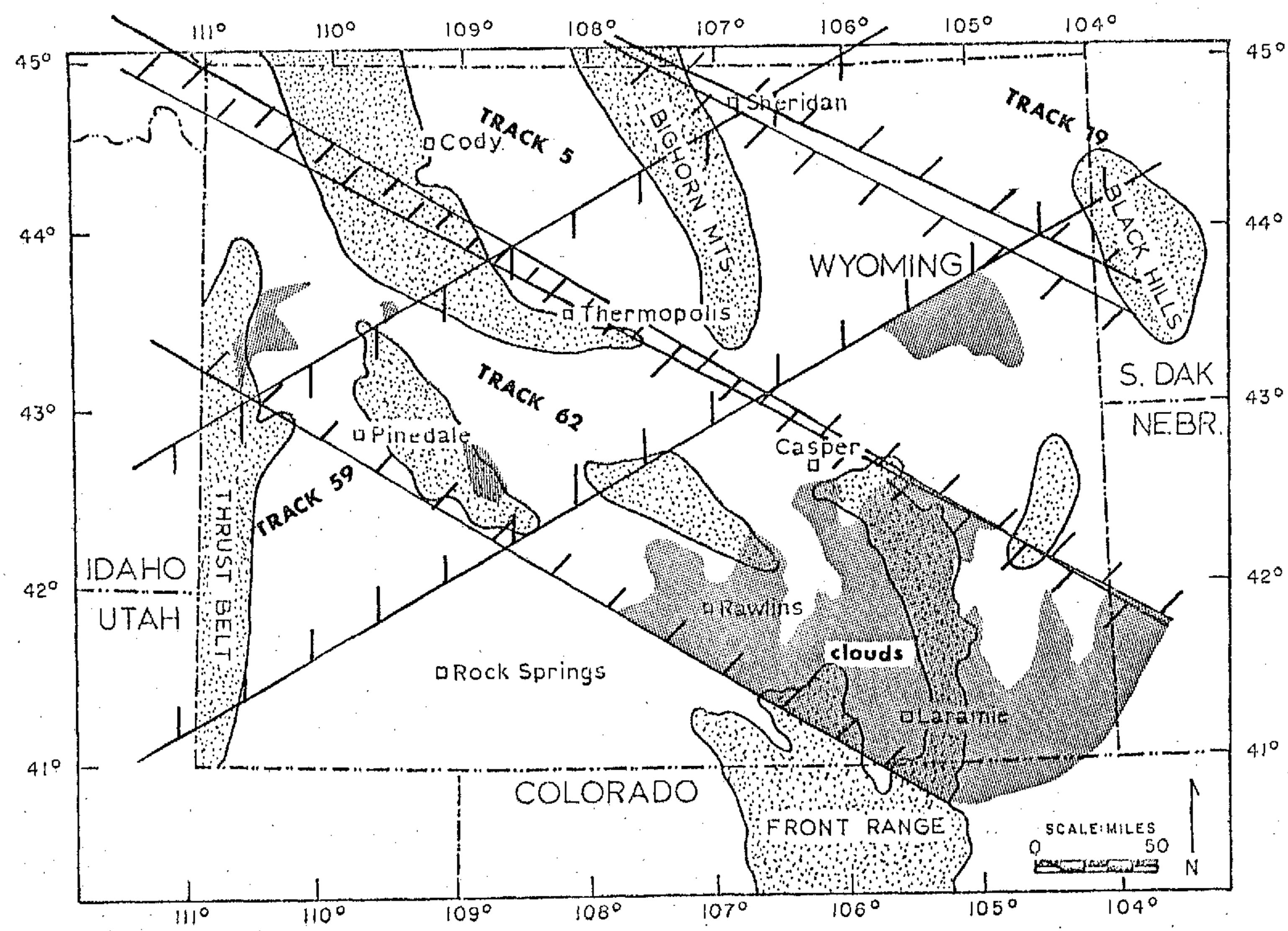


Figure 1. Index map showing Skylab S-190A coverage of Wyoming.
Note: Grey areas indicate cloud cover.

coverage that might be available from "unsuccessful" EREP passes.

The overall quality of the EREP photographic data has been good. Contact transparency images (70-mm S-190A and 4 1/2-in. S-190B) are very good and the enlarged paper prints are generally of high quality. The enlarged transparency images, on the other hand, are poorly exposed and have dust and scratches imaged on the 9-in. duplicates. Improper exposure and poor color balance combined with negative imperfections severly limit the use of the 9-in. transparencies.

Applications of the EREP photography currently being investigated include vegetation mapping (both range and crops), land-use mapping, and various geologic and mineral resources applications. These are discussed individually in the following section.

WORK SUMMARY

Upon receipt of the first EREP data, efforts were made to determine the relative utility of the S-190B photography and the various bands of S-190A photography. Several image enhancement procedures were tested to estimate the potential of image enhancement as an aid in interpretation of the EREP photography.

The resolution of the various photographic products is as expected, with the S-190B having the best resolution, and the color, black and white panchromatic, color infrared, and infrared S-190A images having successively poorer resolution (fig. 2). Resolution of the S-190B photography appears to be about the same (30-40 ft.) for both the color and black and white films. The high-resolution color photography proved to be the "most useful" for general applications because of its high resolution and the readily interpretable color information. This color photography shows surprisingly little effect

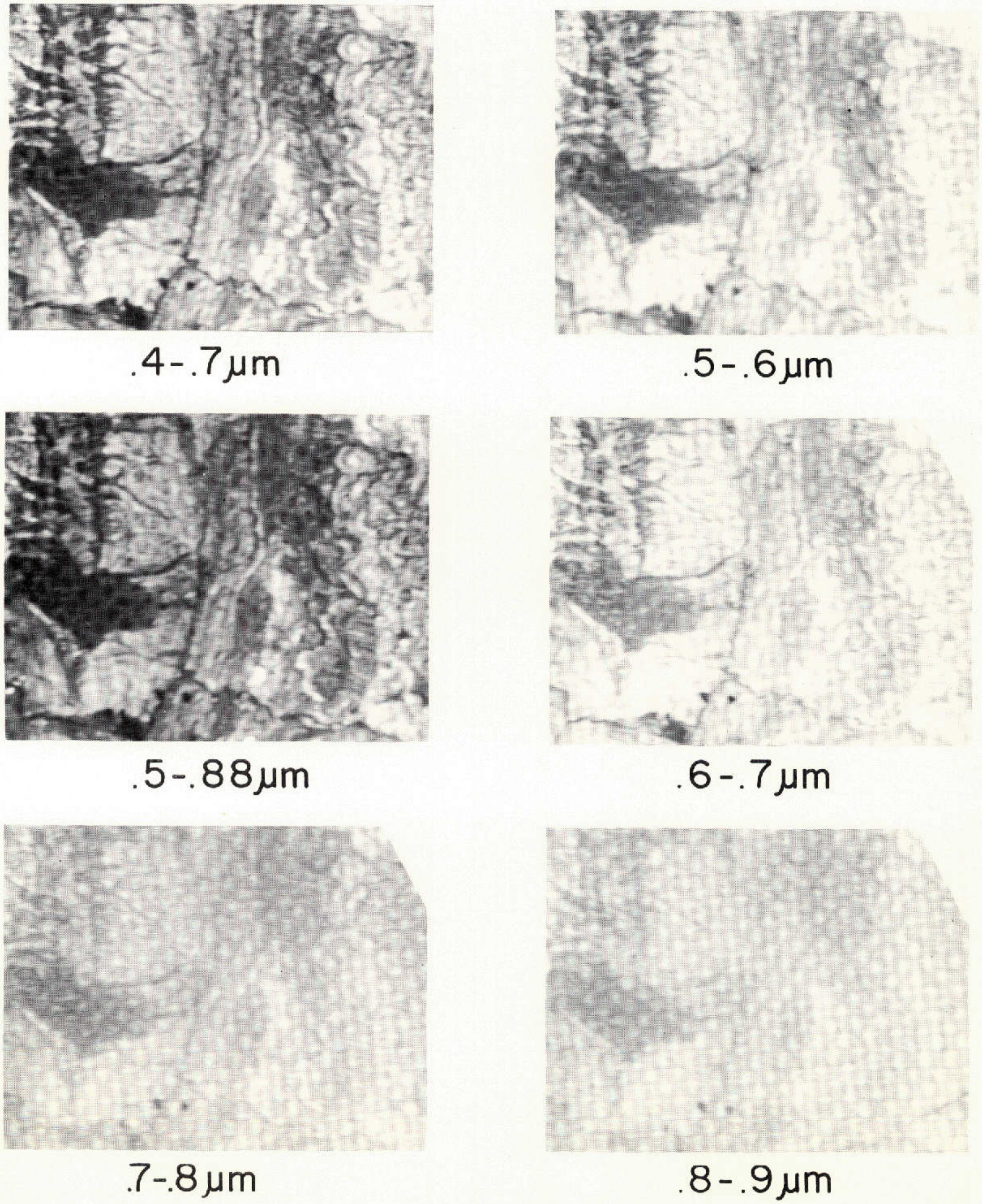


Figure 2. Skylab S-190A resolution comparison. The enlargements shown here represent a small portion of an S-190A photograph of the Wyoming Thrust Belt.

of scattering (haze).

Initial attempts to employ color-additive and color-subtractive viewing techniques were unsuccessful due to anomalous tonal variations across the multiband images (Marrs, 1973b). Upon further investigation these seemingly anomalous color patterns were found to result mostly from contrast differences in the various film products being combined. The red and green-band images have particularly high contrast while the infrared bands are more nearly normal or low-contrast. The additive- and subtractive-composite images were completely dominated by contributions from the red and green bands until steps were taken to adjust image contrasts to comparable levels. The range of contrast variation in the S-190A bands is too large to handle with a standard color-additive system (Spectral Data, model PV-62). Diazo color-combination allows greater flexibility in this regard and we have had considerably greater success in forming diazo color composites.

Image enlargement and isodensity contouring techniques have been particularly helpful in interpretation of the high-resolution EREP photography. Detail available from the EREP photography is far too great to be mapped directly at the scale of the standard image enlargements. Quantitative work with the smaller image features requires enlargement to as much as 20 to 50 times original size and accurate measurement of relative film densities.

In several applications the EREP photography has been compared to both ERTS imagery and high-altitude aircraft photography. We have found that the EREP imagery retains the advantages of synoptic coverage in addition to providing stereoscopic coverage and resolution intermediate between the ERTS imagery and aircraft photography.

One application that illustrates the value of image-enlargement and density analysis is the mapping of strip-mines. Major strip-mines can be identified on ERTS imagery, and, with the aid of density contouring devices, some estimation of their size and general configuration is possible. Aerial photography allows accurate mapping of the mine and identification of areas where different operations are underway. Unfortunately, aircraft data are not available on a periodic basis, as is the ERTS imagery. Recent work with the Skylab S-190B data demonstrates that sufficient detail is recorded on the S-190B photography to allow strip mines and areas of particular mining operations to be identified (fig. 3). These determinations are greatly aided by density analyses and image enlargement. The results of this work suggest that satellite imagery with the resolution of the EREP S-190B photography could be used effectively to monitor large-scale mining operations if such data were available on a periodic basis.

One of the most significant applications of satellite imagery is in the field of regional tectonics and structure. The synoptic coverage unique to satellites provides the broad-scale view necessary for identification of large features that are subtly expressed. The ERTS-1 satellite has provided a wealth of new information that will certainly lead to a better understanding of the structural configuration and geologic history of the earth. EREP S-190A provides comparable synoptic coverage with the higher resolution that enables better identification of observed anomalies and associated features.

Three studies related to regional tectonics are currently underway at the University of Wyoming. They include analyses of drainage patterns in the Beartooth Mountains and Powder River Basin, an analysis of photo-linear features of northeast Wyoming and Southern Montana, and mapping of linear features in the Precambrian rocks of the Wind River Mountains.

Figure 3a. Enlargement of Skylab S-190B image showing the Wyodak coal mine near Gillette, Wyoming.

Figure 3b. Interpreted isodensity contour map compiled from an isodensitracing of the S-190B photograph shown in 3a.

Drainage pattern analysis are intended to define patterns within drainage basins which may be related to structure, lithology, or regional tectonics. The regional scope of the S-190 photography allows relatively rapid assessment of regional drainage patterns. Areas of particular interest can be studied in greater detail by statistical analysis of the drainages.

Analysis of drainage patterns in the Powder River Basin and Beartooth mountains is currently underway. Presently, it appears that drainages of the Beartooth region are controlled chiefly by lithology and fracture patterns. Drainages of the Powder River Basin may reflect a regional tectonic influence. Further study is needed to confirm or disprove these tentative conclusions.

One Wyoming investigator has recently completed statistical analysis of photo linear elements interpreted from the S-190 A photography along tracks 5 and 19 in southern Montana and northeast Wyoming (Fig. 4). The interpreter subdivided the study area into three zones on the basis of the major structural provinces. A rose diagram was constructed for each zone as an indicator of the dominant linear trend. Both mountainous areas (Bighorn/Pryor Mountains and the Beartooth/Crazy Mountains) show a distinct trend perpendicular to the sun azimuth. This dominant trend must be evaluated with the illumination direction in mind because of a tendency for topographically expressed linear elements to stand out sharply when they lie perpendicular to the direction of illumination. Comparison of the rose diagrams shows that the two mountainous zones share northeast and west-northwest sets of linears but each has a second set of linears that has a distinct trend. The Beartooth/Crazy Mountains zone exhibits a set of north-northwest-trending linears while the Bighorn/Pryor zone shows a northwest trend. This same northwest-trend is seen as the only

FOLDOUT FRAME 1

FOLDOUT FRAME 2

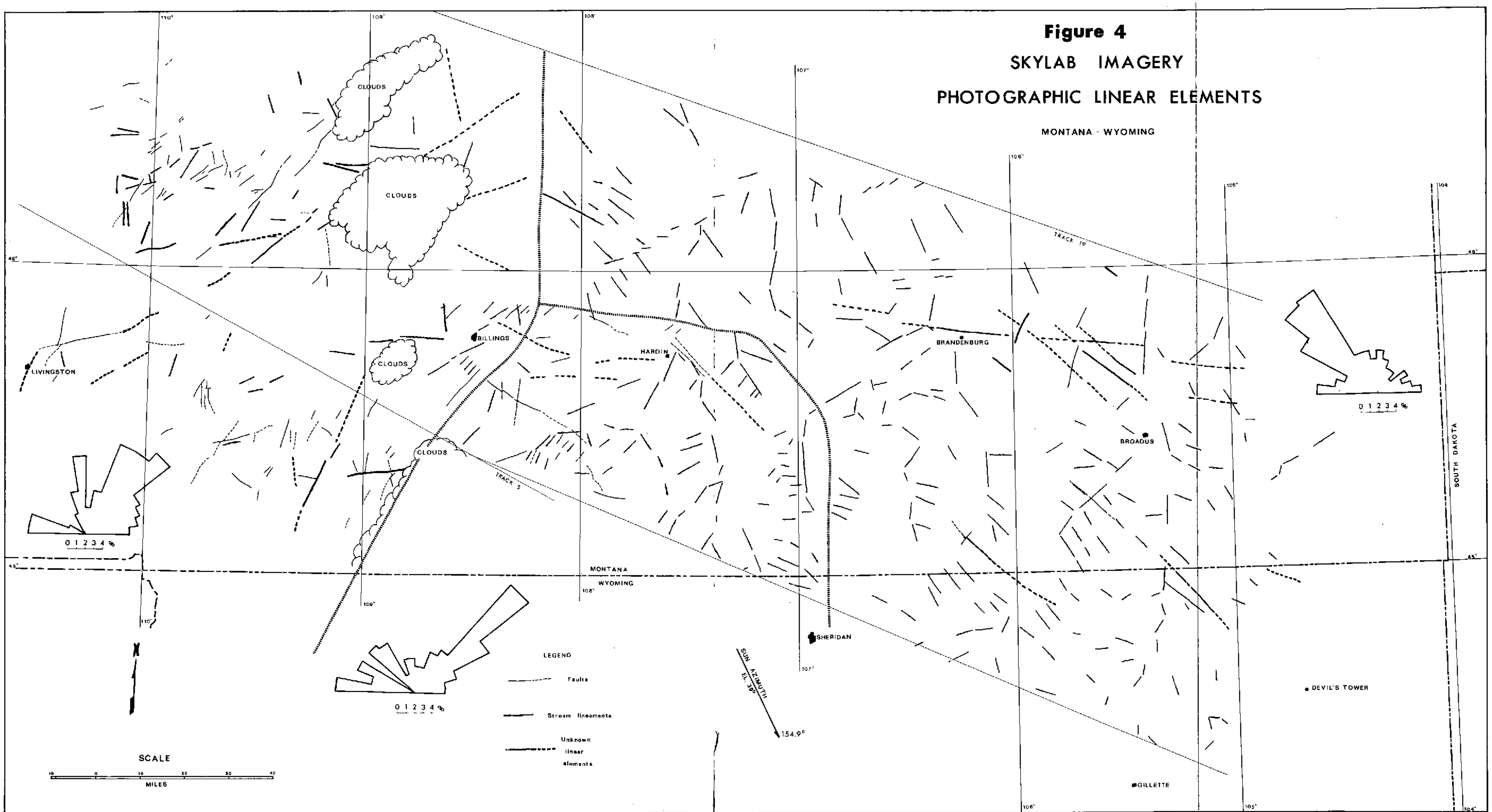


Figure 4

SKYLAB IMAGERY

PHOTOGRAPHIC LINEAR ELEMENTS

MONTANA - WYOMING

strong trend in the Powder River Basin linear elements.

Several hypothesis can be constructed on the basis of these observations. Correlation of the trend in Powder River Basin and Bighorn Mountains linear elements suggests that linear elements in the Powder River Basin are structurally controlled. This is in sharp contrast to the findings of Blackstone (1973b) in similar comparisons of structure in the Bighorn Basin with those of the Bighorn Mountains. Partial correlation of photo linear trends in the Bighorn/Pryor and Beartooth/Crazy Mountain areas may be an indication of kinship through part of geologic history and a divergence of the development of these two areas at some time in geologic history. Conclusions such as these must be checked by investigation of the nature and relative ages of the various features defined from interpretation of the Skylab imagery.

A third study involving photo linear elements is an attempt to define major fracture trends in the Precambrian rocks of the Wind River Mountains. Initially, it was hoped that this study could help to define the relative utility of the EREP S-190A photography as compared to the ERTS multispectral scanner imagery and high-altitude aircraft imagery. A separate interpretation of the Skylab and ERTS imagery was made for a portion of the Wind River Range (Fig. 5). Comparison of the two resulting photolinear maps revealed a distinct difference in the dominant photo linear trend. This difference correlates with the difference in the directions of illumination. Because the resulting photo linear maps are obviously affected by the illumination direction, no definite conclusions could be drawn regarding the relative utility of the ERTS and EREP data.

Continued work with photo linear elements should supplement our knowledge of structural interrelationships, regional tectonics, and geologic history

Figure 5a. Portion of enlarged Skylab S-190A image 205 from EREP pass 28, Sept. 13, 1973. Area outlined corresponds to linear features map of Figure 5b.

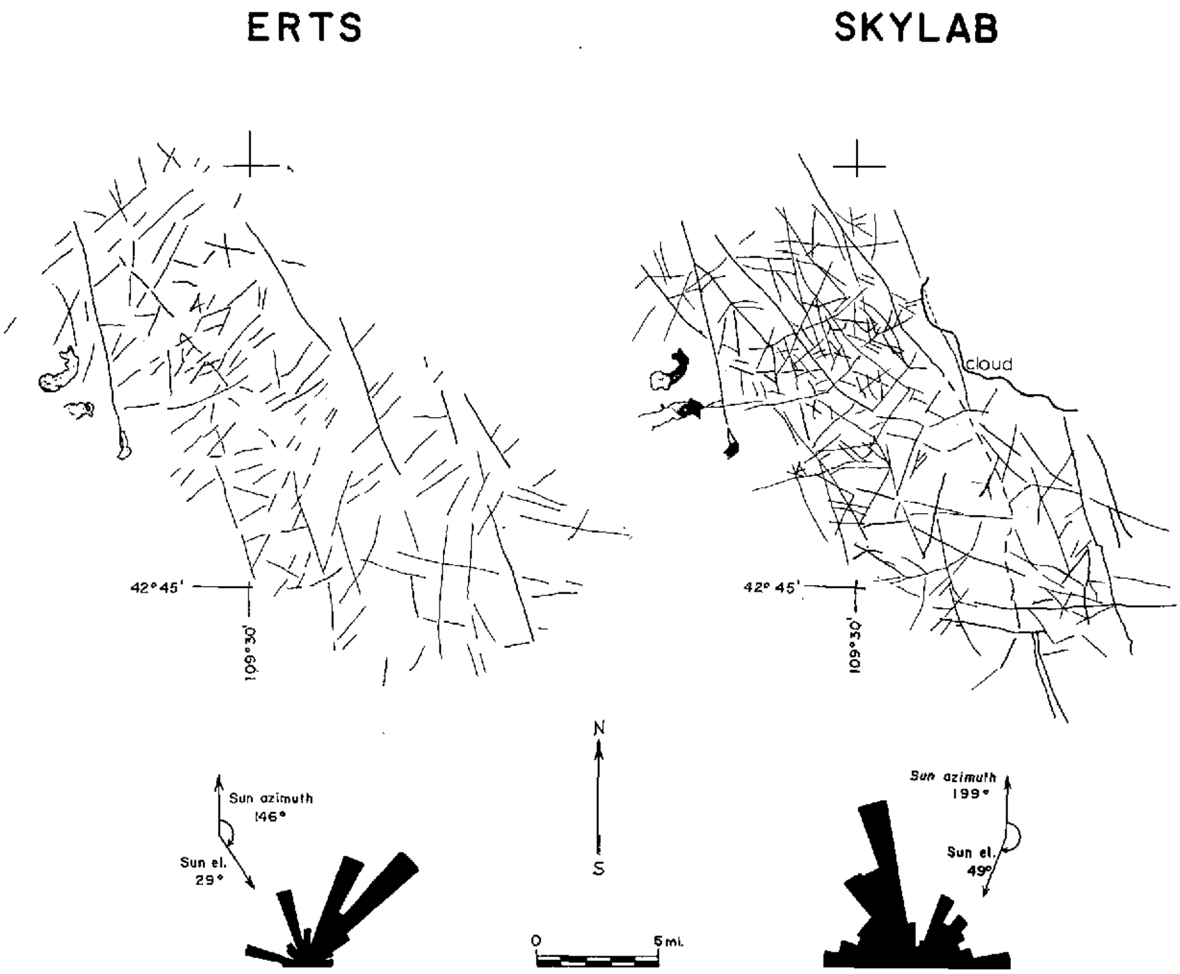


Figure 5b. Photo linear elements along the southwestern flank of the Wind River Mountains, Wyoming.

to such an extent as to allow more efficient exploration, development, and management of natural resources. Lithologic information derived from interpretation of color, tone, texture, and geomorphologic patterns, together with the structural and tectonic data offers the opportunity to construct better geologic maps than are presently available for most of the United States.

Four studies now underway will test the EREP S-190 photography as a geologic mapping tool. In one study the EREP S-190 B photography is used to map lithologic outcrops in the Tertiary and Cretaceous units of the Powder River Basin and western Black Hills. In this region, the geologic structure is relatively simple but the lithologic contrasts are often very subtle.

An outcrop map was constructed for the Tertiary and Cretaceous rocks in the Black Hills/Northern Powder River Basin area of Montana and Wyoming using Skylab S-190 B imagery (Figs. 6 and 7). Contacts were, for the most part, easily located, especially when adjoining formations were of significantly different lithology to exhibit contrasting geomorphic and physical characteristics. In some instances, formal geologic units were necessarily combined simply because they were not distinguishable on the Skylab photography.

The Tertiary Fort Union formation is of particular interest because different units within the formation were mappable. Unfortunately the Lebo and Tullock members of the Fort Union formation could not be differentiated but the Tongue River member was easily divided into a lower unit, characterized by rugged badlands topography, and an upper unit, characterized by mesa-type topography. This division, although striking on the imagery, may not be geologically significant. The lower unit may only have been more thoroughly eroded than the upper unit (the outcrop area of lower unit is dominated by the Powder River drainage system). However, coal and baked shale appear to be more abundant in the lower photomap unit.

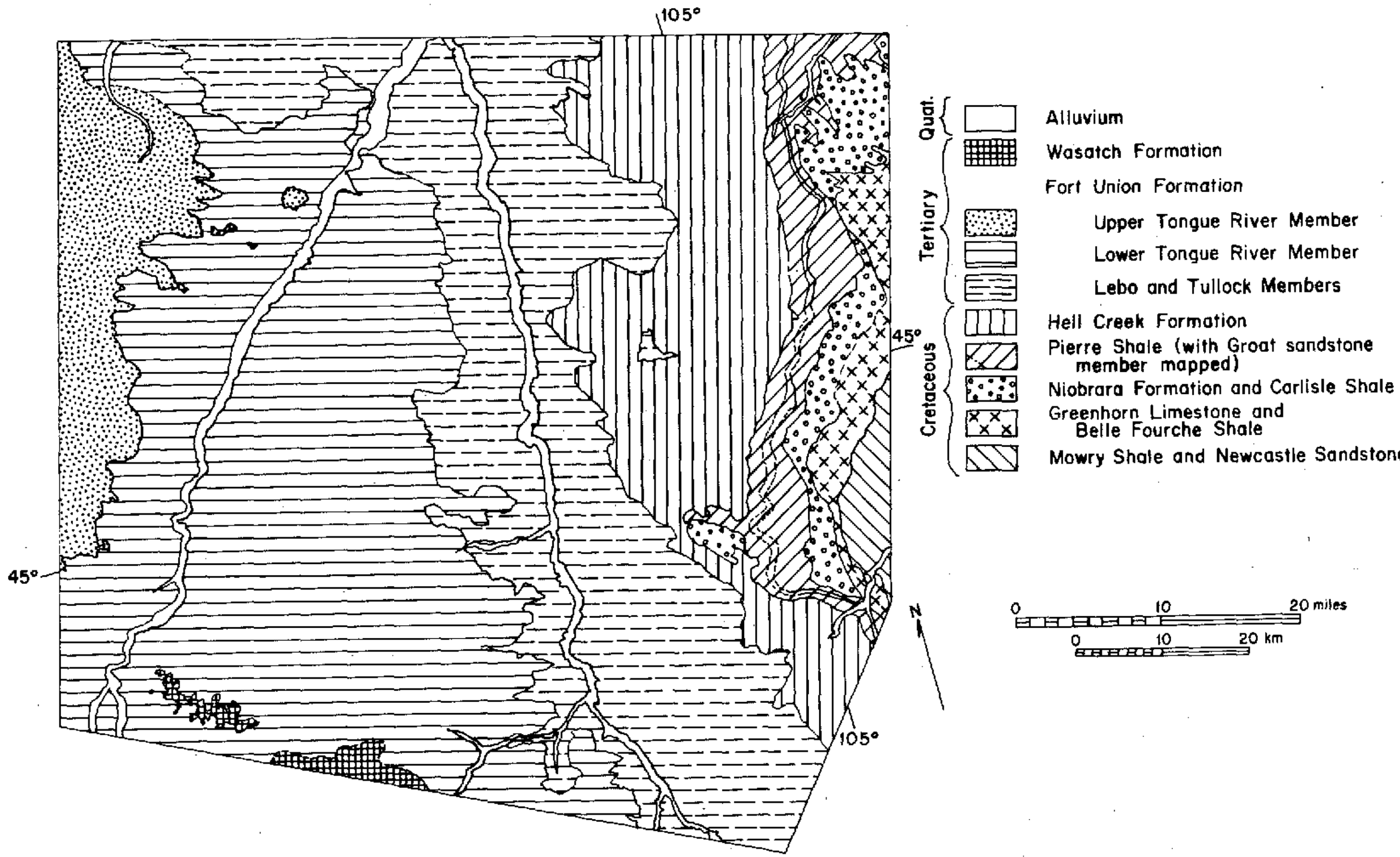


Figure 6. Outcrop map of the Black Hills/Powder River Basin area of northeast Wyoming (interpreted from Skylab, S-190B, color photography).

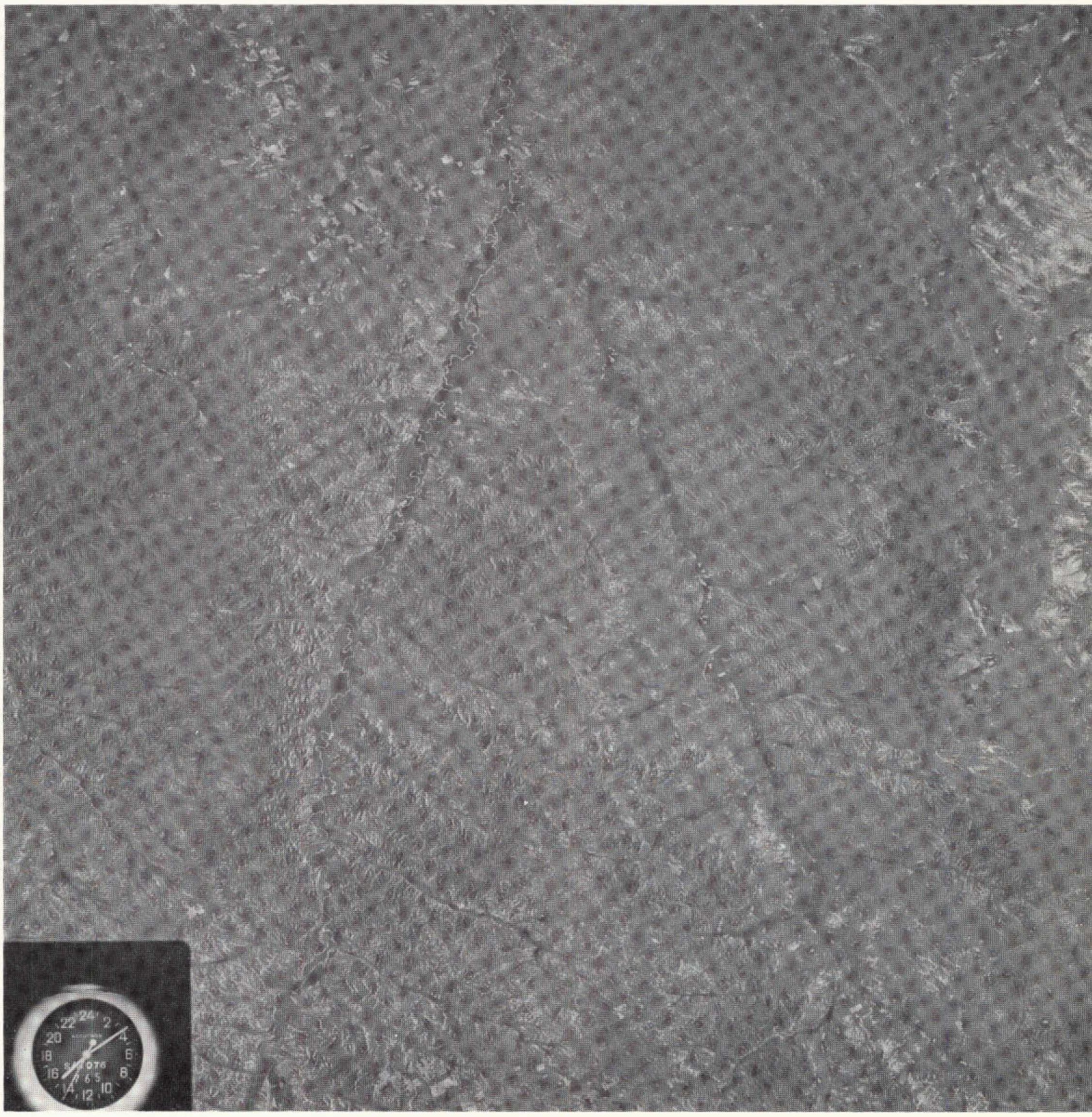


Figure 7. Halftone reproduction of Skylab S-190B color photograph 81-153, track 19. The area shown is a portion of the Powder River Basin lying immediately west of the Black Hills.

In some areas of the Powder River Basin coal beds become ignited and burn for some distance along and into the outcrop. Heat produced by the burning coal causes the overlying rock (usually shale) to become baked and reddened. Areas of burned coal can often be mapped through delineation of baked shale outcrops.

Outcrops of baked shale in the lower Tongue River member of the Tertiary Fort Union formation were mapped using the Skylab S190B imagery (Fig. 8). Difficulties in locating contacts arose because baked shale occurs in more than one horizon of the unit, with white-to-yellow sandstone between the horizons. Therefore, the map only generalizes the location of specific beds. The baked horizons vary widely in degree of oxidation, consequently there are differences in hue and resistance to erosion. Highly oxidized horizons are relatively easy to delineate but contacts between slightly oxidized beds and unbaked strata appear vague, especially when highly oxidized beds occur nearby.

A second study in geologic mapping involves the Tertiary and Quaternary sedimentary units of the northern Green River Basin. Here the structure is relatively simple but lithologic distinctions are generally subtle. The chief difference between this study area and that of the Powder River Basin is in the geomorphology and vegetative cover. The Powder River Basin area is minutely dissected by small ephemeral streams and supports a vegetation community typical of the high plains, short-grass prairie. The Green River Basin is a more arid intermontane basin which is, by comparison, very sparsely vegetated. Consequently, the interpreter was better able to distinguish the subtle differences between lithologic units of the Green River Basin. The resulting map (Fig. 9) compiled from interpretation of the EREP S-190 A color photography (Fig. 10) compares favorably to the Wyoming State Geologic Map

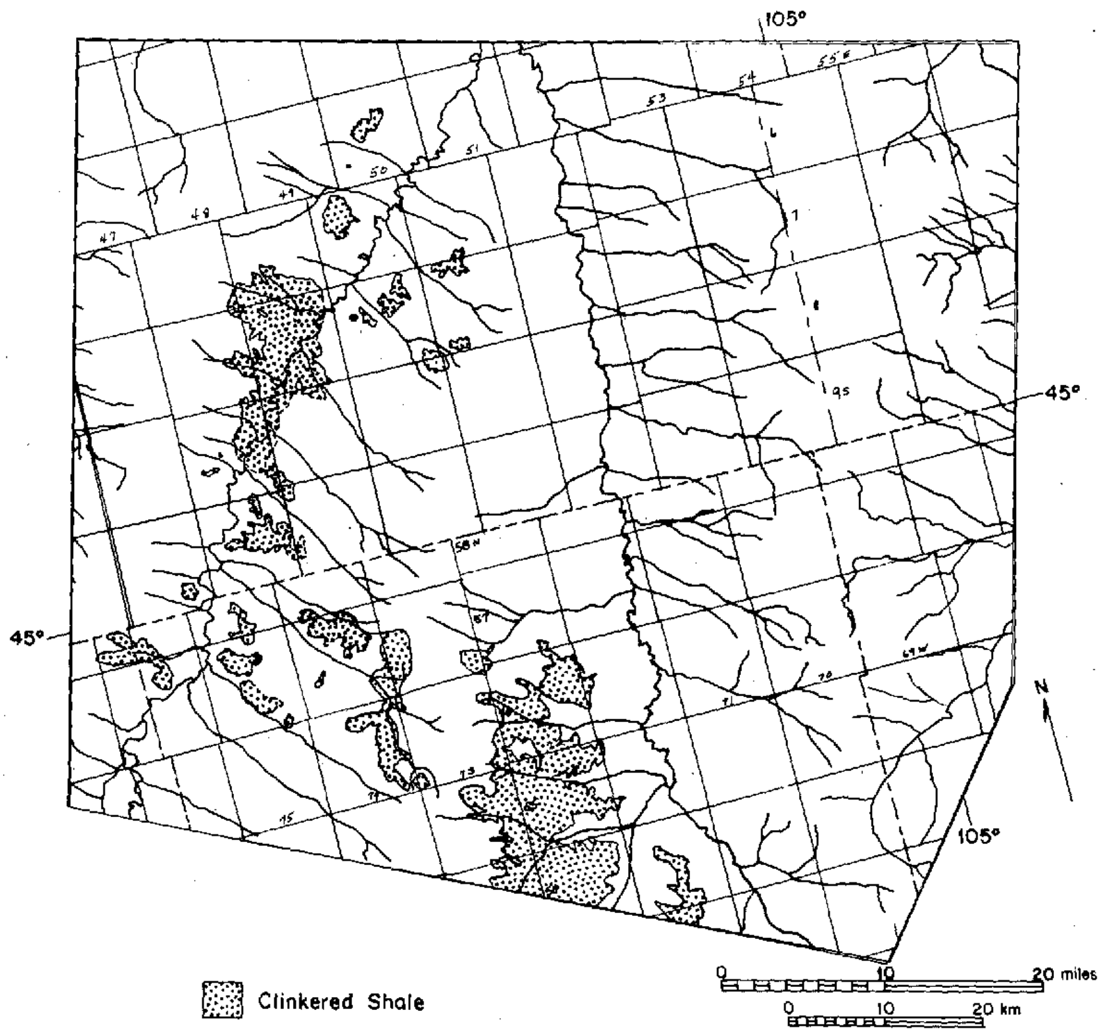
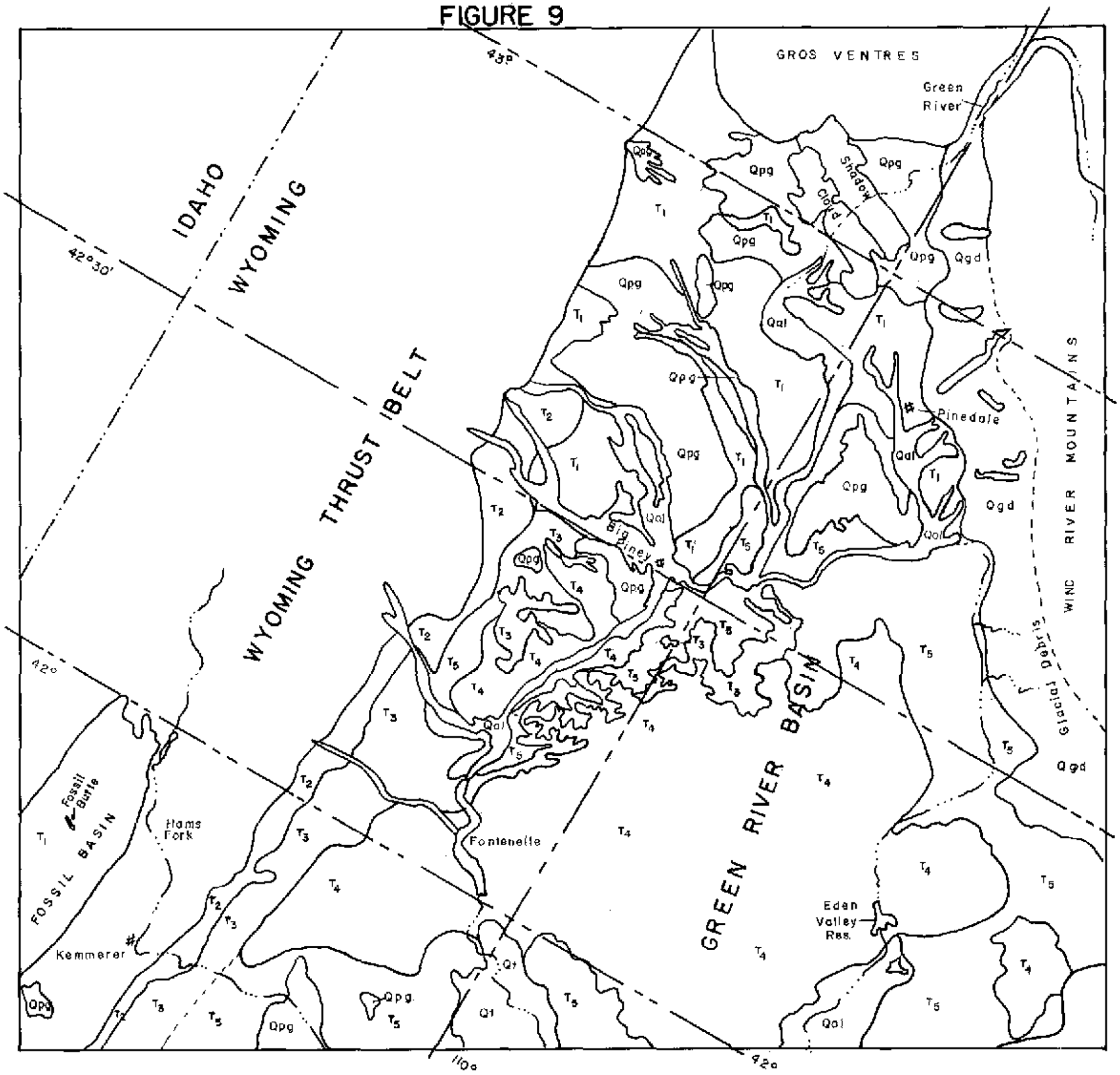


Figure 8. Map of baked shale outcrops in the Powder River Basin of northeast Wyoming (interpreted from Skylab, S-190B, color photography).

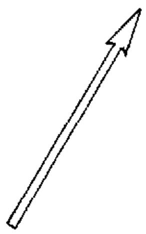
FIGURE 9



GEOLOGIC MAP OF THE GREEN RIVER BASIN, WYOMING INTERPRETED FROM SKYLAB IMAGE # 204, TRACK 59

Qal	Quaternary Alluvium
Qpg	Quaternary Pediment Gravels
Qt	Quaternary Terrace Gravels
Qgd	Quaternary Glacial Debris
T_5, T_4, T_3, T_2, T_1	Various Tertiary Units Differentiated On Color Basis

NORTH



0 13 26

Scale: Miles

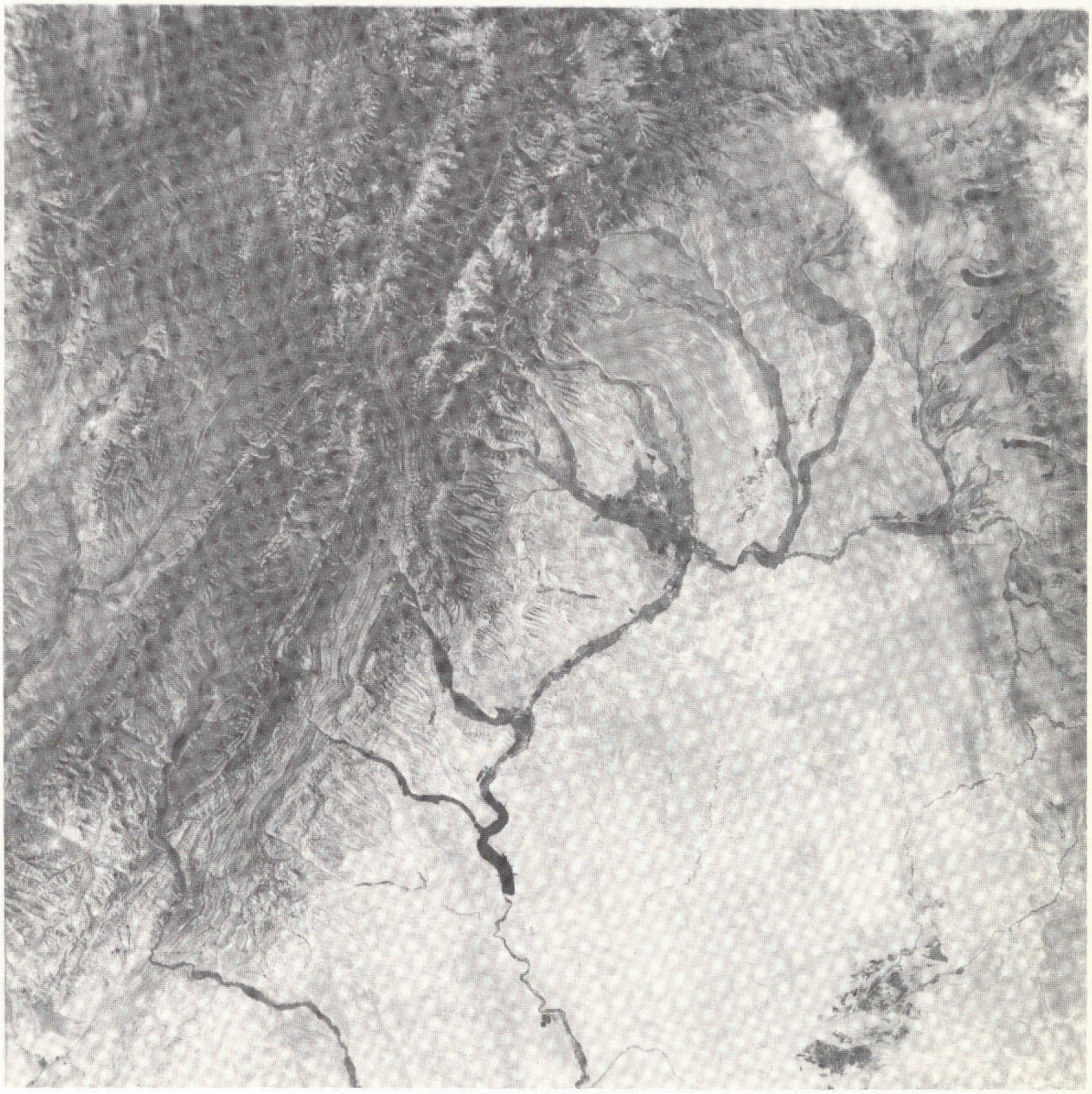
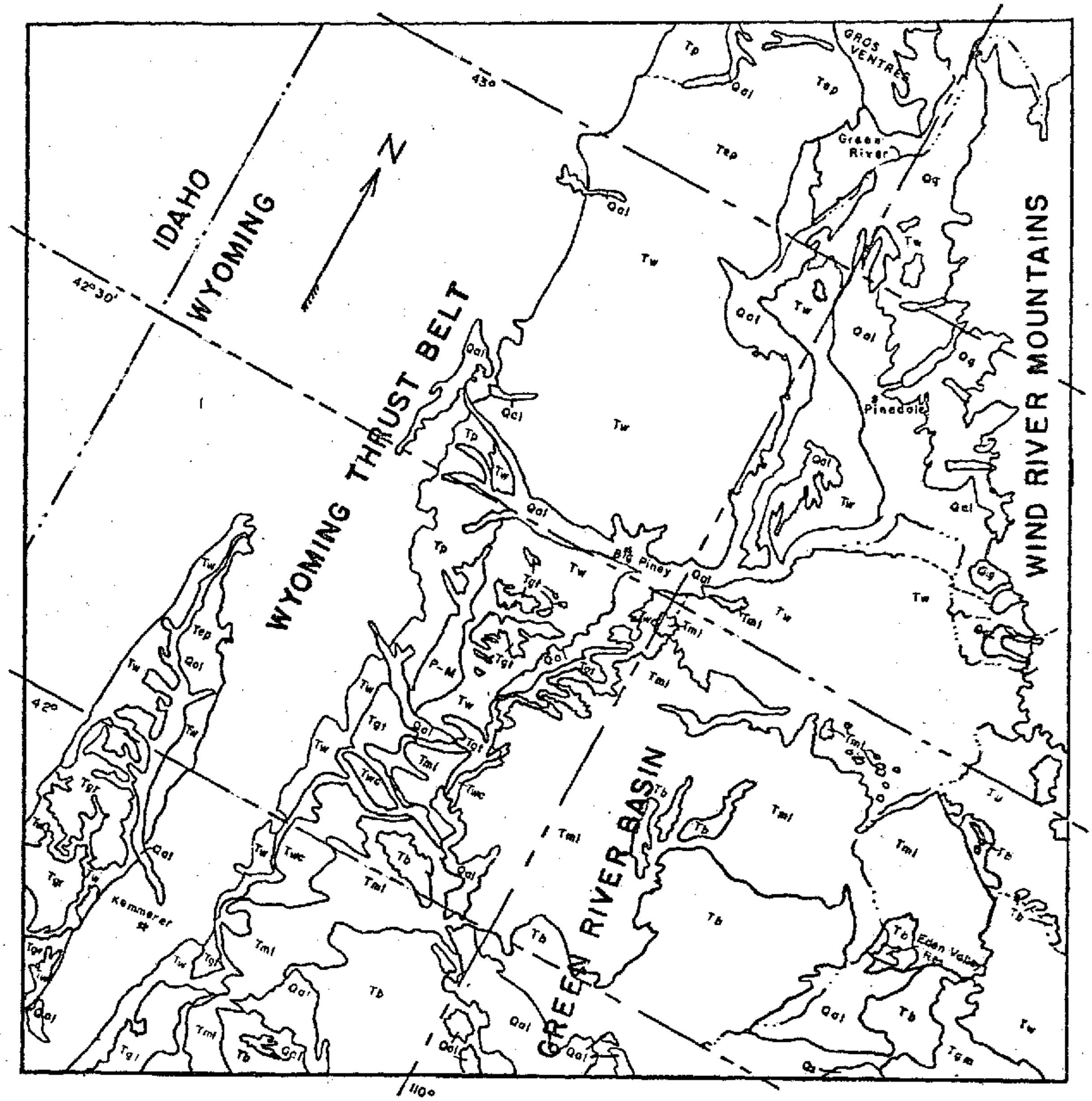


Figure 10. Skylab S-190A image 204 (red band) from EREP pass 28, September, 1973. Image area includes parts of the Wyoming Thrust Belt, the Green River Basin, and the Wind River Mountains.



Scale 1/500,000

Qg	Glacial deposits	Tml	Morrow Creek and Leney members
Qal	Alluvial deposits	Tgt	Tipton Shale member
Qs	Wind Blown sand	Twc	Cathedral Bluffs tongue
Tb	Bridger Formation	Tp	Paleocene Rocks Undivided
Tgr	Green River Formation	Tep	Lower Eocene and Paleocene Rocks
Tgm	Morrow Creek member	Tu	Tertiary Rocks Undivided
Tw	Wasatch Formation	P-M	Paleozoic and Mesozoic Undivided

Figure 11. Geologic map of the Green River Basin, Wyoming

(after Love and others, 1955)

(Fig. 11) but reflects a somewhat different subdivision of geologic units in some parts of the area. Some formations were not identifiable by photo-interpretation. Others could be split into several units or facies.

The area mapped as Tertiary undivided (T_1) comprise Paleocene and Eocene sedimentary units including the Wasatch and Green River Formations. The Wasatch Formation has more reddish hue around the western margin of the Green River Basin than in the center of the basin. The interpreter failed to recognize the outcrops of Wasatch in the central part of the Basin as distinct from parts of the Bridger formation and included them in the area mapped as T_5. This photo-map unit includes all the Bridger and Wasatch sedimentary rocks which have a distinct bluish-green cast on the S-190 A color photography. The unit mapped as T_4 includes the Morrow Creek and Laney Members of the Green River Formation as well as units of the Bridger and some outcrops of Wasatch Formation. The areas mapped as T_3 are the lighter-colored units of the Green River Formation -- chiefly oil shale and marlstone of the Tipton member. Quaternary photomap units correspond quite well to those of the Wyoming Geologic Map and, in fact, the contacts mapped from the EREP photography may be somewhat more accurate than the corresponding contacts on the state geologic map.

The Green River Basin study demonstrates the value of EREP photography for producing a photomap that can be readily transformed into a geologic map by field checking and comparison with available data. The chief problem is the lack of complete correspondence between the formal geologic units and the mappable photogeologic units.

Another mapping study has been undertaken in the structurally complex area near Greybull, Wyoming. Here, Paleozoic and Cretaceous, sedimentary rocks are complexly folded and faulted. Some lithologic contrasts are relatively sharp, allowing distinction of very thin rock formations. These units can be used effectively as "marker" beds and provide a reference datum for much of the structural interpretation.

The photogeologic map (Fig. 12a) compiled from interpretations of the EREP S-190 B photography of the area (Fig. 13) shows considerably more detail than the 1:500,000-scale Wyoming Geologic Map (Love and others, 1955) and, in fact, the interpretation shows more detail than the 1:125,000 field geologic map (Fig. 12b, Anderson and others, 1947). As might be expected, some of the formal geologic do not correspond precisely to the major units mapped on the photo interpretation. The overall structural configuration indicated on the two maps is similar, but the EREP photointerpretation reveals greater structural detail and a number of possible faults not shown on the geologic map.

Dr. R. S. Houston is currently preparing a geologic map of a fourth area, the Horn area near Buffalo, Wyoming. This area has previously been mapped from ERTS imagery and high-altitude aerial photography. The completed maps should allow comparisons regarding the utility of the different data type for general geologic mapping. Results of this study will be discussed in detail in a later special report.

Dr. R. W. Marrs has begun a study using the EREP S-190 A imagery to locate possible mineral prospects through mapping of zones of altered rock in the Absaroka Mountains of northeast Wyoming. The altered rock has a tendency to appear slightly more reddish than the country rock, but the distinction between altered and unaltered rock is extremely subtle and is often masked by snow, vegetative cover, or differences in slope angle. Interpretation of the S-190 A imagery (Fig. 14) yielded a preliminary alteration map showing several irregular areas of possible exposed alteration (Fig. 15). Such areas proved difficult

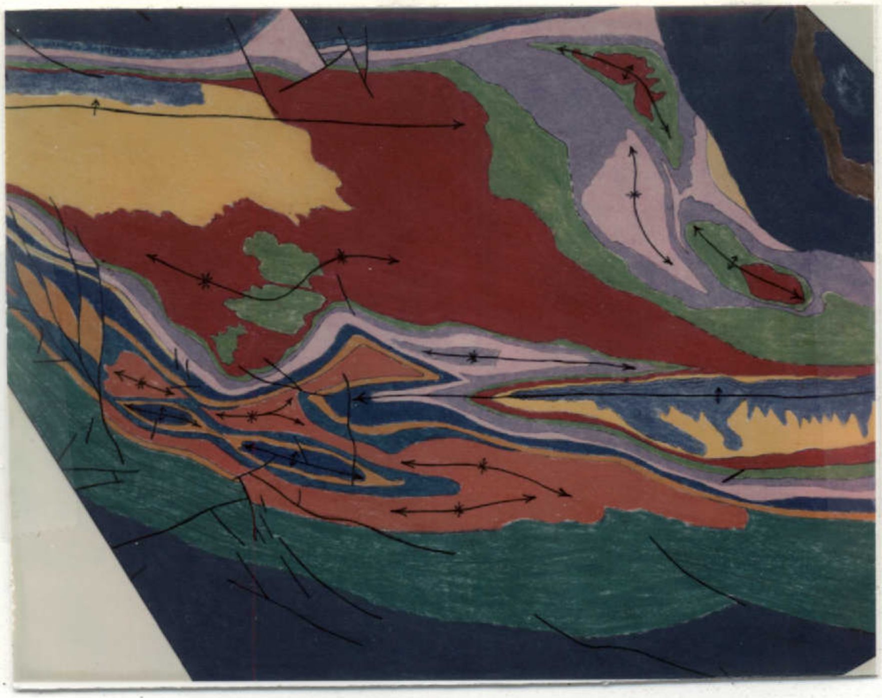


Figure 12a. Photogeologic map of the Sheep Mountain area near Greybull, Wyoming interpreted from Skylab S-190A photography along Track 5, June 13, 1973.

Figure 12b. 1:125,000-scale field geologic map of the Sheep Mountain area near Greybull, Wyoming (after Andrews and others, 1947).

Figure 13. Skylab S-190B photograph of Sheep Mountain area (Frame 144, Roll 13, Track 5, EREP Pass 10). Outlined area corresponds to map area of Figure 12.

Figure 14. Skylab S-190-A photograph of Absaroka Range and Beartooth Mountains, Wyoming and Montana (Frame 225, Roll 15, Track 5, EREP Pass 10).

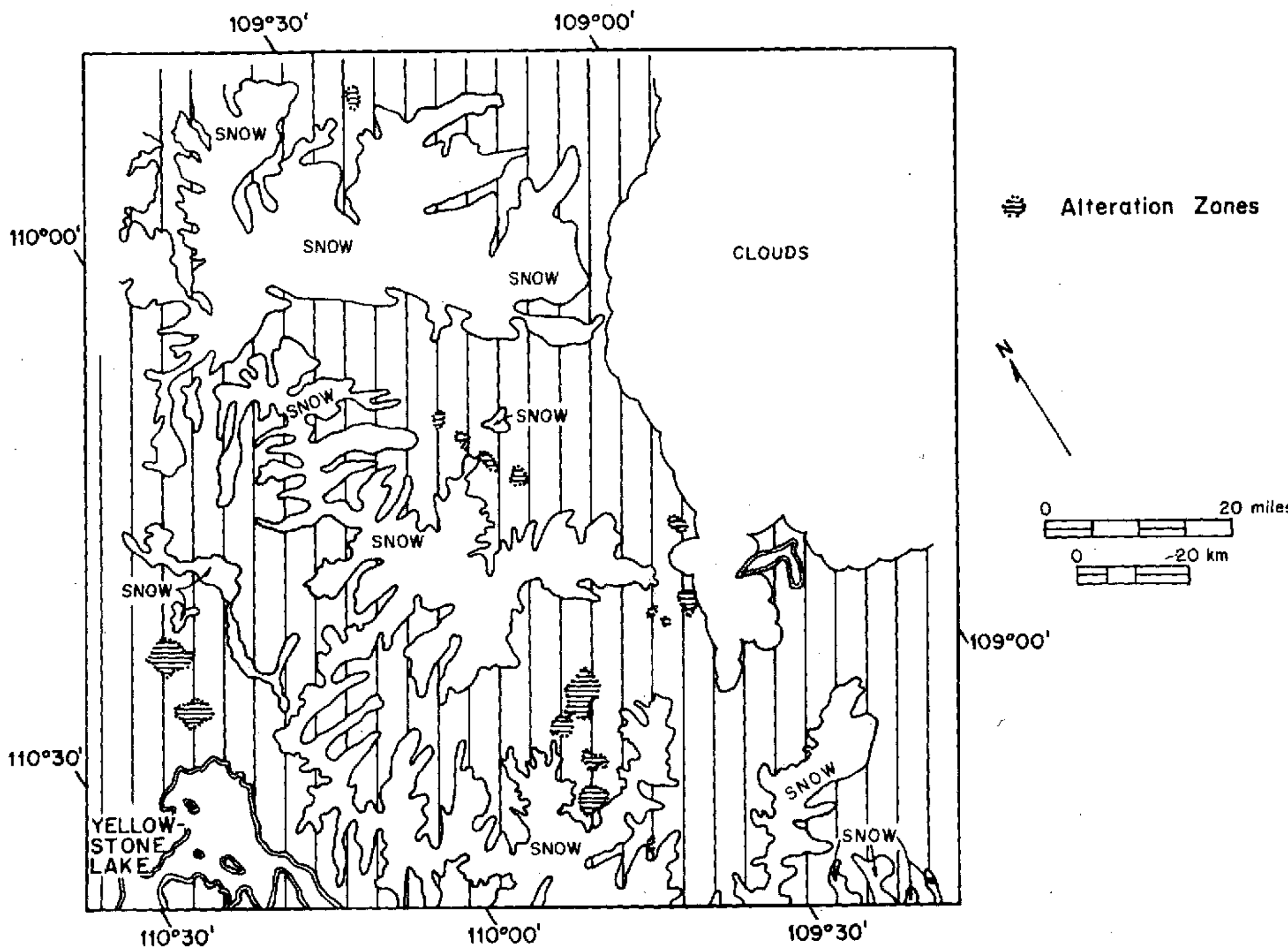


Figure 15. Map of possible alteration zones in the Absaroka region of northwest Wyoming (interpreted from Skylab, S-190A, color photography).

to locate and almost impossible to delineate. Further confirmation of this interpretation is required before it is subjected to field checking. Anticipated confirmation procedures include 1) correlation with other interpretations made independently by other investigators 2) correlation with maps of photo linear elements (because mineralization tends to be fault controlled), and 3) supplemental interpretation of various "enhanced" images in which attempts will be made to minimize interfering contrasts.

A similar attempt to use ERTS-1 imagery for locating alteration zones and related fractures (Breckenridge, 1973) also produced questionable results. The color anomalies could not be accurately delineated by standard photo-interpretive techniques and, thus far, enhancement procedures have not been employed successfully. Possible anomalies located from ERTS-1 image interpretations have not yet been field checked.

Land-use applications of EREP S-190 photography have, thus far been limited to local applications. Plant-science and land-use investigators at the University of Wyoming have used the EREP S-190 B imagery (Fig. 16) to map and identify crop types in the Riverton Area. The mapped area was first subdivided into broad land-use categories (water, rangeland, area of mineral extraction, farmland, etc.). A concerted effort was then made to subdivide the irrigated farmland and identify major crops (Fig. 17). The resulting crop map was formally compared to recent, high-altitude aerial photographs and checked against available field observations. It was determined that individual fields are generally mappable and major crops can be identified with surprising accuracy.

A somewhat more demanding application of EREP data to land-use is the study of Wyoming strip mines mentioned earlier in this report. Initial tests

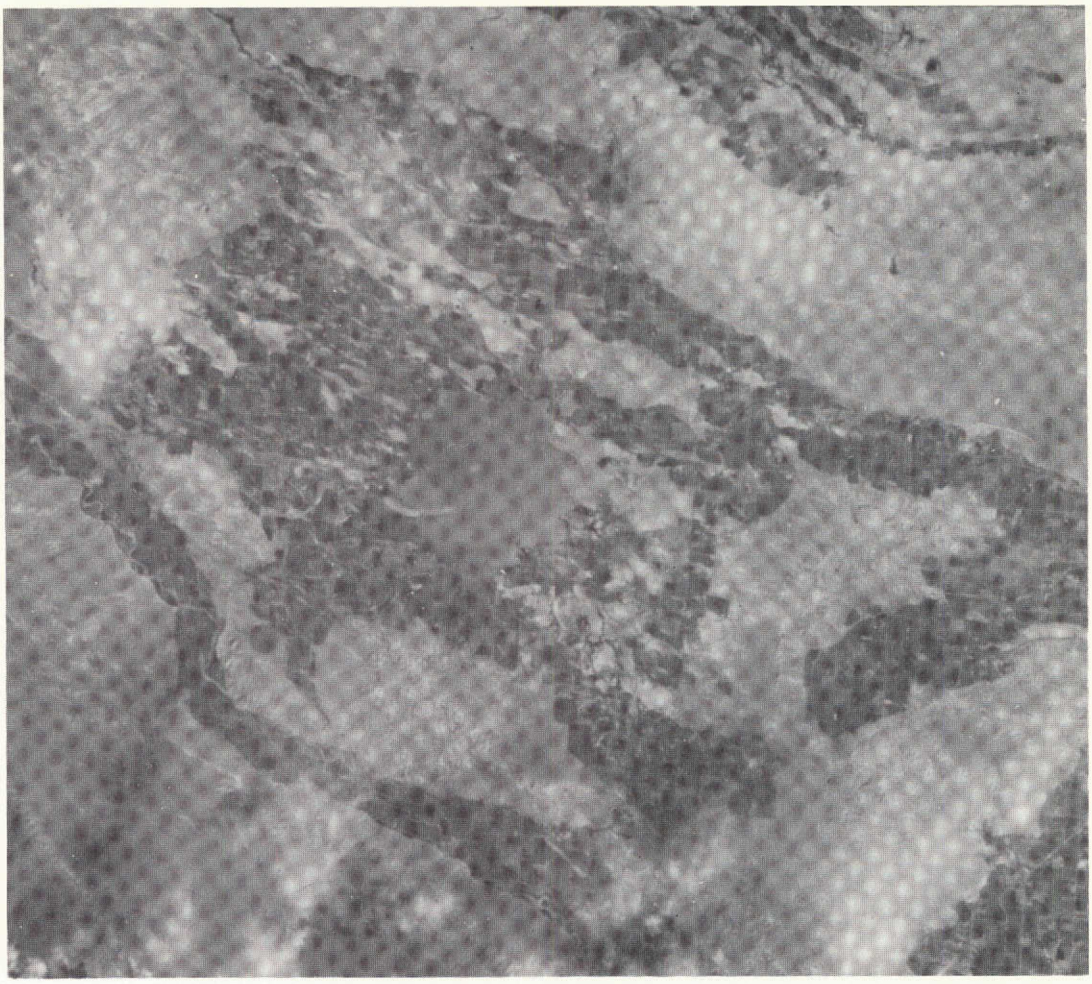
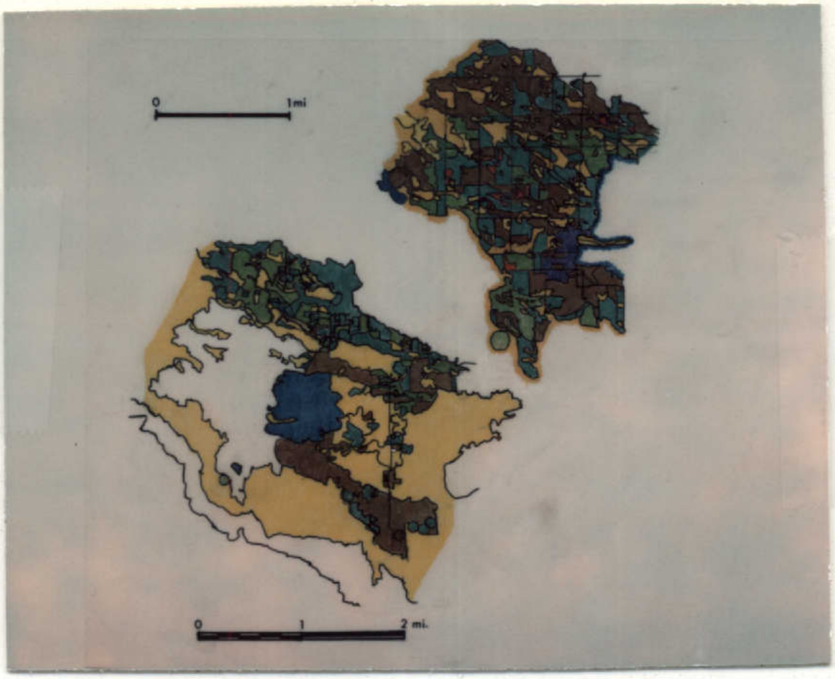


Figure 16. Portion of Skylab S-190B photograph showing the Riverton agricultural area. S-190B, S1-3, Track 62, Pass 4, August 5, 1973.



DELINEATION OF VEGETATION TYPES FROM SKYLAB IMAGERY

GENERAL CLASSIFICATION

- Sagebrush-grassland
- Pasture
- Irrigated crops
- Irrigated crops

DETAILED CLASSIFICATION

- Sagebrush
- Grass
- Pasture
- Pasture, high moisture
- Corn
- Alfalfa
- Sugar beets
- Unclassified
- Small grain (barley)

- Water
- Type boundaries and roads

Figure 17. Agricultural use map of Riverton area interpreted from Skylab S-190B photography.

were conducted on the Wyodak coal mine near Gillette. The results have been very encouraging. Photographic interpretation of the EREP photography, supplemented with isodensity analysis allows the areas of major mine operations to be located and identified. The EREP data are far superior to ERTS imagery in this regard.

We have not yet applied EREP photography to any specific problems of urban land-use but we have made preliminary evaluations of the EREP data for cities of Buffalo, Gillette, and Rapid City. Street patterns and relative difference in urban developments are readily discernable. Some effects of the 1972 Rapid City flood can be recognized and areas of new industrial and urban buildup can be located. The EREP photography will obviously be of considerable assistance in updating land-use and city-planning maps.

SUMMARY OF SIGNIFICANT RESULTS

Investigation of a variety of applications of EREP photographic data demonstrated that the EREP S-190 data offer a unique combination of synoptic coverage and image detail. The broad coverage is ideal for regional geologic mapping and tectonic analysis while the detail is adequate for mapping of crops, mines, urban areas and other relatively small features.

The investigative team at the University of Wyoming has applied the EREP S-190 data to 1) analysis of photolinear elements of the Powder River Basin, southern Montana and the Wind River Mountains 2) drainage analysis of the Powder River Basin and Beartooth Mountains 3) lithologic and geologic mapping in the Powder River Basin, Black Hills, Green River Basin, Bighorn Basin and Southern Bighorn Mountains, 4) location of possible mineralization in the Absaroka Range, and 5) land-use mapping near Riverton and Gillette. All of these applications were successful to some degree. Image enhancement procedures were useful in some efforts requiring distinction of small objects or subtle contrasts.

PROBLEMS AND RECOMMENDATIONS

Chief problems encountered in the Wyoming investigation are the lack of coverage of several prime test areas and the delayed receipt of some data products. Problems resulting from lack of coverage may be partially alleviated if data are supplied for portions of attempted passes that may contain useful data. These data have been requested.

The delayed receipt of some data products is a more serious problem. We have, as yet received no processed S-192 data (selected processing of S-192 scanner data was requested on the basis of screening film). Shipments of photographic data are sometimes incomplete, and as yet we do not have the full complement of S-190 data for two of the four successful (or partially successful) EREP passes over Wyoming. Shipment of sensor correlation reports have also been spotty. We have not received sensor tabulations for EREP passes completed on Skylab Mission 3 and have received some tabulations that are obviously incorrect.

Of these data shortages we view the situation with the S-192 data as most serious. With proper processing and interpretation, multispectral scanner may prove to be a most valuable tool. Continued delay of this data may jeopardize the intended studies involving the S-192 data.

We are currently compiling an up-to-date list of data "received" and "not received" to be submitted to NASA in the hope that the needed data products will be supplied.

SUMMARY OUTLOOK

Studies to date indicate that the S-190 A and S-190 B photography will meet or exceed the investigative requirements if the necessary coverage can be obtained. We believe we can successfully complete the investigative objectives. We have experienced some delays in data receipt that have required postponment of some investigative activities. Consequently, investigative progress and spending is somewhat behind schedule. A portion of this lag may be compensated by increased activity throughout the remainder of the scheduled contract period, but we now anticipate a somewhat delayed contract completion date. Present estimates indicate that contract completion may be delayed as much as 4 or 5 months.

We are very encouraged by the degree of success achieved in the applications of EREP that have been attempted thus far. We anticipate many other successful applications as the investigation progresses.

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