2 N76-21654

N76-21654 ~~F76-11725~~

NASA CR- C.1
147543

EXPERIMENT TO EVALUATE THE FEASIBILITY OF UTILIZING SKYLAB-EREP REMOTE SENSING DATA FOR TECTONIC ANALYSIS THROUGH A STUDY OF THE BIG HORN MOUNTAIN REGION, WYOMING, SOUTH DAKOTA AND WYOMING

Richard A. Hoppin, Principal Investigator
Department of Geology
University of Iowa
Iowa City, Iowa 52242

Research Assistants
James Caldwell, Donald Lehman, Steven Palmer
Kuo-Liang Pan, Alan Swenson

NAS9-13313
EREP 303393

March 1976

Final Report for Period April 1973-September 1975

Prepared for
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas 77058

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EXPERIMENT TO EVALUATE THE FEASIBILITY OF UTILIZING SKYLAB-EREP REMOTE SENSING DATA FOR TECTONIC ANALYSIS THROUGH A STUDY OF THE BIG HORN MOUNTAIN REGION, WYOMING, SOUTH DAKOTA AND WYOMING		5. Report Date March 1976 6. Performing Organization Code
7. Author(s) Richard A. Hoppin		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Geology University of Iowa Iowa City, Iowa 52242		10. Work Unit No. 11. Contract or Grant No. NAS9-13313
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION JOHNSON SPACE CENTER, Houston Texas 77058 DAVID L. AMSBURY, TECHNICAL MONITOR		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

S190A, S190B and S192 data were obtained from all SKYLAB missions. S190B imagery was the best single product from which fairly detailed structural and some lithologic mapping could be accomplished in the Big Horn basin, the Owl Creek Mountains, and the northern Big Horn Mountains. The Nye-Bowler lineament could not be extended east of its presently mapped location although a linear (fault or monocline) was noted that may be part of the lineament, but north of postulated extensions. Much more structure was discernible in the Big Horn basin than could be seen on LANDSAT-1 imagery; RB-57 color IR photography, in turn, revealed additional folds and faults. A number of linears, several of which could be identified as faults and one a monocline, cut obliquely the east-west trending Owl Creek uplift. The heavy forest cover of the Black Hills makes direct lithologic delineation impossible. However, drainage and linear overlays revealed differences in pattern between the areas of exposed Precambrian crystalline core and the flanking Paleozoic rocks. S192 data, even precision corrected segments, was not of much use. All S190A products were found to have advantages under certain special conditions. SKYLAB photography was found to provide the means to obtain quite good structural information in areas not covered by younger Tertiary formations.

17. Key Words (Suggested by Author(s))	18. Distribution Statement		
Geologic Remote Sensing Skylab Earth Resources Experiment Satellite Photography			
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 52	22. Price*

*For sale by the National Technical Information Service, Springfield, Virginia 22161

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLES

1.0 INTRODUCTION

1.1 Background

The Principal Investigator (PI) and his students have been carrying out geological investigations in the Big Horn region since 1954. The major goal has been to work out the structural history of this area. This has been accomplished through areal mapping projects and detailed structural analysis of portions of both the Precambrian core and the overlying sedimentary rocks.

A synthesis of these detailed surface studies and of other published and unpublished work has led to the recognition of five different Tertiary structural elements in the Big Horn Mountain Region (Hoppin and Jennings, 1971). Of particular interest are long east-west lineaments which cross the uplifts and may extend into the adjoining basins (Fig. 1). Only one (Tensleep Fault) has been well located; four others have been partially located with varying degrees of confidence on the basis of ground mapping and interpretation of aerial photographs. The lineaments are variously expressed as faults, brecciated zones, and mineralized fracture zones within the uplift and as boundaries marking abrupt terminations and/or bends in axial traces of folds in the adjacent basins. Other structural elements recognized are 1) northwest trending folds in the basins and, locally, on the flanks of the Big Horns, 2) the large, arcuate, convex eastward uplift consisting of the Pryor, Big Horn, Bridger, and Owl Creek ranges, 3) N. 10°W. to N. 10°E. high angle faults and monoclinal flexures in the uplifts and 4) overthrust and underthrusts along segments of the flanks of the Big Horns.

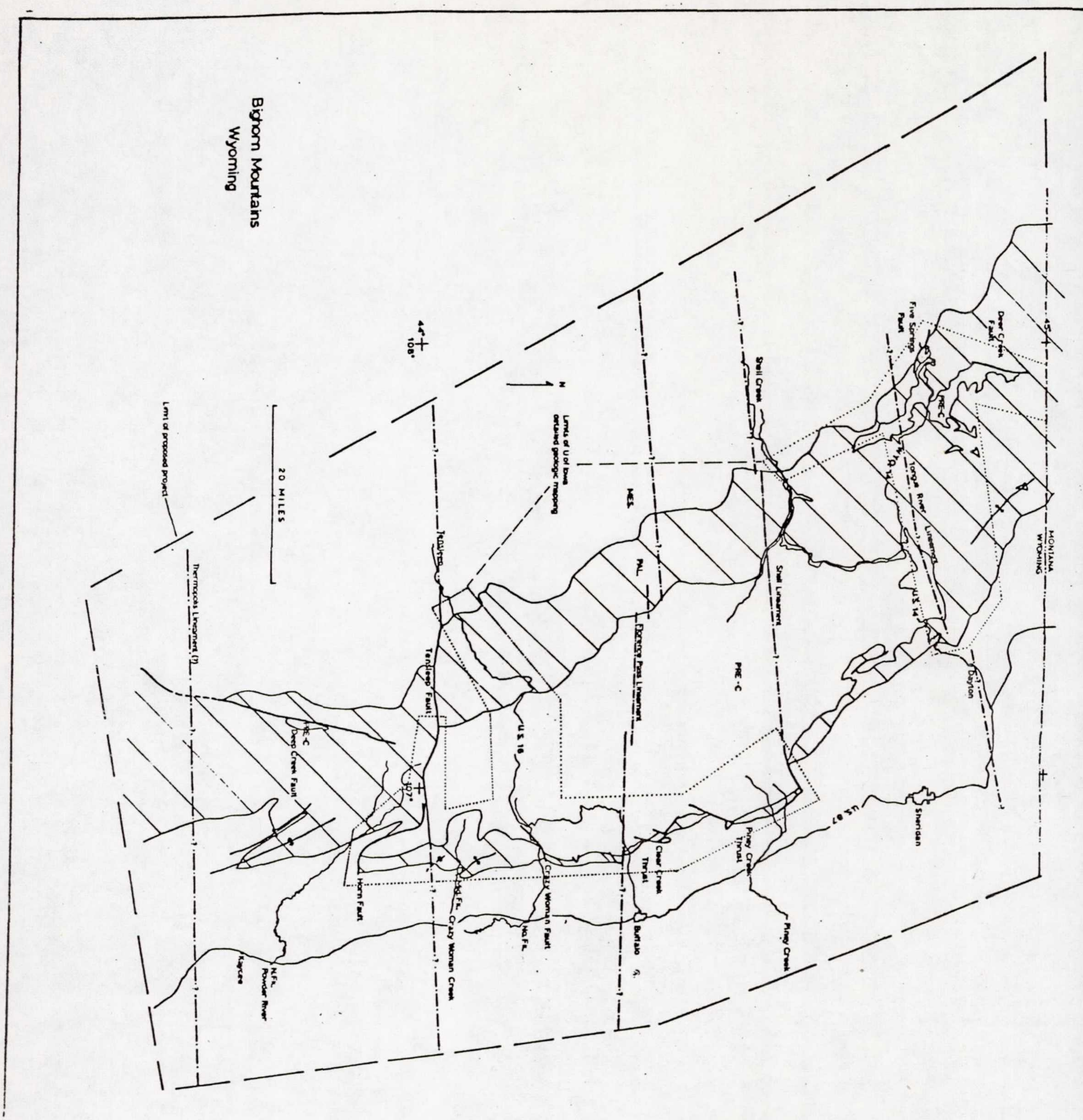


Fig. 1 Lineaments as proposed from geologic studies.

TABLE 1

SKYLAB-2 Imagery Inventory

I. S-190A Multispectral Camera
  A. Pass #6; Billings, Mont. to the Badlands, S. Dakota
    1. 70 mm black & white Positives; frames #104-118
       (no 70 mm color or color IR)
    2. 9" x 9" Positives and Negatives (black & white only)
       (a) frames #104-118 (black and white)
       (b) frames #112-126 (color/color IR)
    3. Cloud cover minimal
    4. Stereo overlap; 60%

  B. Pass #10; Beartooth Mountains, Mont. to NW Nebraska
    1. 70 mm black and white Positives; frames #203-222
       (no 70 mm color or color IR)
    2. 70 mm Negatives (produced from positives); frames #210-214
    3. 9" x 9" Positives and Negatives (black and white only)
       (a) frames #203-222 (black and white)
       (b) frames #220-239 (color/color IR)
    4. Cloud cover >50%: frames #203, 218; >80% frames #219-222
    5. Stereo overlap; 60%

II. S-190B Earth Terrain Camera
  A. Pass #6 (color)
    1. Frames #81-146 thru 81-164
       (4 1/2" x 4 1/2" and 9" x 9" transparencies)
    2. Cloud cover minimal
    3. Stereo overlap; 60%

  B. Pass #10 (Black and White)
    1. Frames 82-136 thru 82-158 (4 1/2" x 4 1/2" and 9" x 9" and transparencies)
    2. Negatives
       (a) 9" x 9" all frames
       (b) 4 1/2" x 4 1/2"; frames 82-143 thru 82-148
    3. Cloud cover >50%; frames 141, 142, 154; >80%; frames 155-158
    4. Stereo overlap; 60%

III. S-192 Multispectral Scanner
  A. Passes #6 and 10]
     Channels #2, 7, 11] screening film
  B. Pass #10; 555-1 Interim Final Product; Channels #1-14 and 17-22
  C. Precision corrected segments of bands 1-12, 13-2, Pass #6, Roll 915, Pass #10, Roll 916

TABLE 2

SKYLAB-3 Imagery Inventory

I. S-190A Multispectral Camera
   A. Pass #37; S. Idaho to Yellowstone Lake
      1. 70 mm Positives; frames #150-153
      2. 9" x 9" Positives and Negatives; frames #149-153
      3. Cloud cover >40%; frames #152, 153
      4. Stereo overlap; 15%

   B. Pass #39; Great Salt Lake to Black Hills
      1. 70 mm Positives; frames #203-215
      2. 9" x 9" Positives and Negatives; frames #203-215
      3. Cloud cover >40%; frames #206, 208-210; 213-215
      4. Stereo overlap; 60%

II. S-190B Earth Terrain Camera
   A. Pass #37 (Color)
      1. Frames 86-332 thru 86-341 (4 1/2" x 4 1/2" only)
      2. Cloud cover >25%; frames #334, 335
      3. Stereo overlap; 10%
      4. Frames 332, 333 dark (underexposed?)
      5. Film advance reversed

   B. Pass #39 (Color)
      1. Frames 88-014 thru 88-023 (4 1/2" x 4 1/2" only)
      2. Cloud cover >50%; frames #017, 019, 022, 023
      3. Stereo overlap - 10%
      4. Film advance reversed

   C. Pass #45 - 1 frame S-73-35081

III. S-192 Multispectral Scanner
   A. Pass #39; Channels #2, 7, 11 (Screening film)
   B. Pass #39 - Precision corrected segment, Boysen Reservoir-Owl Creek Mountains

TABLE 3

SKYLAB-4 Imagery Inventory

I. S-190A Multispectral Camera

A. Pass #85; S. Montana to Black Hills
1. 70 mm Positives; frames #140-151
2, Cloud cover >50%; frames #140-144
3. Stereo overlap; 60%

B. Pass #88; Beartooth Mtns. to Powder River Basin
1. 70 mm Positives; frames #239-252
2. Cloud cover >50%; frames 239-246
3. Heavy snow cover
4. Stereo overlap; 60%

II. S-190B Earth Terrain Camera
A. Pass $85 (Color)
1. Frames #92-158 thru 92-173 (4 1/2" x 4 1/2" and 9" x 9" transparencies)
2. Cloud cover >50%; frames 92-158 thru 92-162
3. Stereo overlap; 60%
4. Bluish tint to imagery
5. Film advance reversed

B. Pass #88 (Color IR)
1. Frames 93-120 thru 93-137 (4 1/2" x 4 1/2" and 9" x 9" transparencies)
2. Cloud cover >50%; frames 93-120 thru 93-130
3. Heavy snow cover
4. Stereo overlap; 60%
5. Greenish tint to imagery
6. Film advance reversed

III. S-192 Multispectral Scanner
A. Passes #85, 88 and 92
B. Channels #2, 7, and 11; 13-1, Pass #92

The writer was also Principal Investigator in an ERTS-1 (LANDSAT-1) project covering the same area. ERTS imagery did not provide evidence that the lineaments could be traced into the basins. It did result in a revision of the location of the Shell lineament and provided no verification of the existence of the eastern part of the proposed Thermopolis lineament. It established the existence of the Tongue River lineament and revealed several previously unknown lineaments in the southern Big Horns and in the Owl Creek Mountains (Hoppin, et al 1973; Swenson, 1973).

One of the reasons for proposing this region for a project area was the considerable ground truth available in addition to the PI's considerable experience in the region. Image interpretations could be compared with previously published maps and supplemented by field checking.

1.2 Objectives of this study.

Original objectives were 1) to detect and map major lineaments, 2) to determine whether large scale structural blocks postulated on the basis of earlier surface mapping could be verified on EREP imagery, 3) to delineate glacial features, 4) to locate anticlines and monoclines, 5) to map major rock types.

Lineaments loom large in any tectonic analysis (Hoppin, 1974), particularly in the light of current theories of lateral movements of large lithospheric plates. It is important that we more precisely determine the presence or absence of these lineaments and define their characteristics. In the last two years, unfortunately, a number of papers have postulated large scale horizontal movements along these and similar lineaments; not only have these investigators called for net slips of sense and amount far different from those actually known, but also they have not placed the lineaments on their maps with the proper directions.

These lineaments might be entirely Tertiary in age and may be crustal adjustments above overidden transform faults or they may represent reactivated zones of deformation along much older, even Precambrian, lines of weakness.

On the basis of earlier interpretations the mapped lineaments were extended into the basins. It is possible to extend some through hot springs areas such as Cody and Thermopolis in the Big Horn Basin and Hot Springs in the southern Black Hills. One can also speculate that the area of Tertiary igneous activity in the northern Black Hills lies along one or more of these lineaments.

The lineaments, if real, may prove to have considerable importance in the search for minerals. Gold has been mined along the Tensleep Fault at the intersection with the extension of the NNE-trending Deep Creek fault. This trend has so far only been reported in the uplifts, but quite possibly could be present in the basins. Such mineral deposits as the uranium of Pumpkin Buttes in the Powder River Basin and along the west flank of the Black Hills, and other metalliferous occurrences in the Black Hills may be located along and at intersections of these two trends.

Through combinations of lack of coverage, clouds and snow-cover, analysis of the central Big Horns was almost completely ruled out. This considerably restricted lineament analysis and the checking of block patterns and completely eliminated glacial studies. As a result of this certain restricted areas were chosen for analysis of some lineaments, anticlines and monoclines and lithologies. With these restrictions in useful coverage, some positive results were, nevertheless forthcoming.

2.0 Methods of analysis.

2.1 Imagery available.

S-190A, S-190B, and S-192 imagery was obtained from all three missions. S-109A areal coverage is shown in Figure 2 and that of S-190B in Figure 3. An inventory of each of the missions is summarized in Tables 1, 2, and 3.

In addition two RB-57 flights, color IR, were made along track 5, (Sept. 17, 1973) from Beartooth Mountains to northwestern Nebraska and along track 59 (Sept. 18, 1973) from Wind River Mountains to the northwestern Black Hills. Track 5 is entirely free of clouds. Track 59 has broken cumulus at the southwest end becoming clear over the Wind River except for a cloud patch over northeast flank, thin clouds and haze from Ocean Lake across Boysen reservoir and Owl Creek Mountains, clear over southern Big Horns, two small areas of thin haze and clouds over Powder River Basin, becoming overcast at northeast end.

The project area was previously covered by ERTS-1 MSS imagery, several U-2 flight strips in color or color IR, and two low altitude (30,000 ft) color IR strips across the Big Horns, all obtained through the ERTS-1 project. Also, almost complete coverage (except for northern Black Hills) of the high altitude panchromatic black and white photography was obtained through both the ERTS and SKYLAB programs.

2.2 Methods of imagery analysis

Standard photo interpretation techniques were employed. All transparencies were studied stereoscopically and/or microscopically on light tables using binocular micro stereoscopes, magnifying glasses, and a Bausch and Lomb stereozoom binocular microscope-Richards light table combination. Overlays of several types (key beds structure; drainage

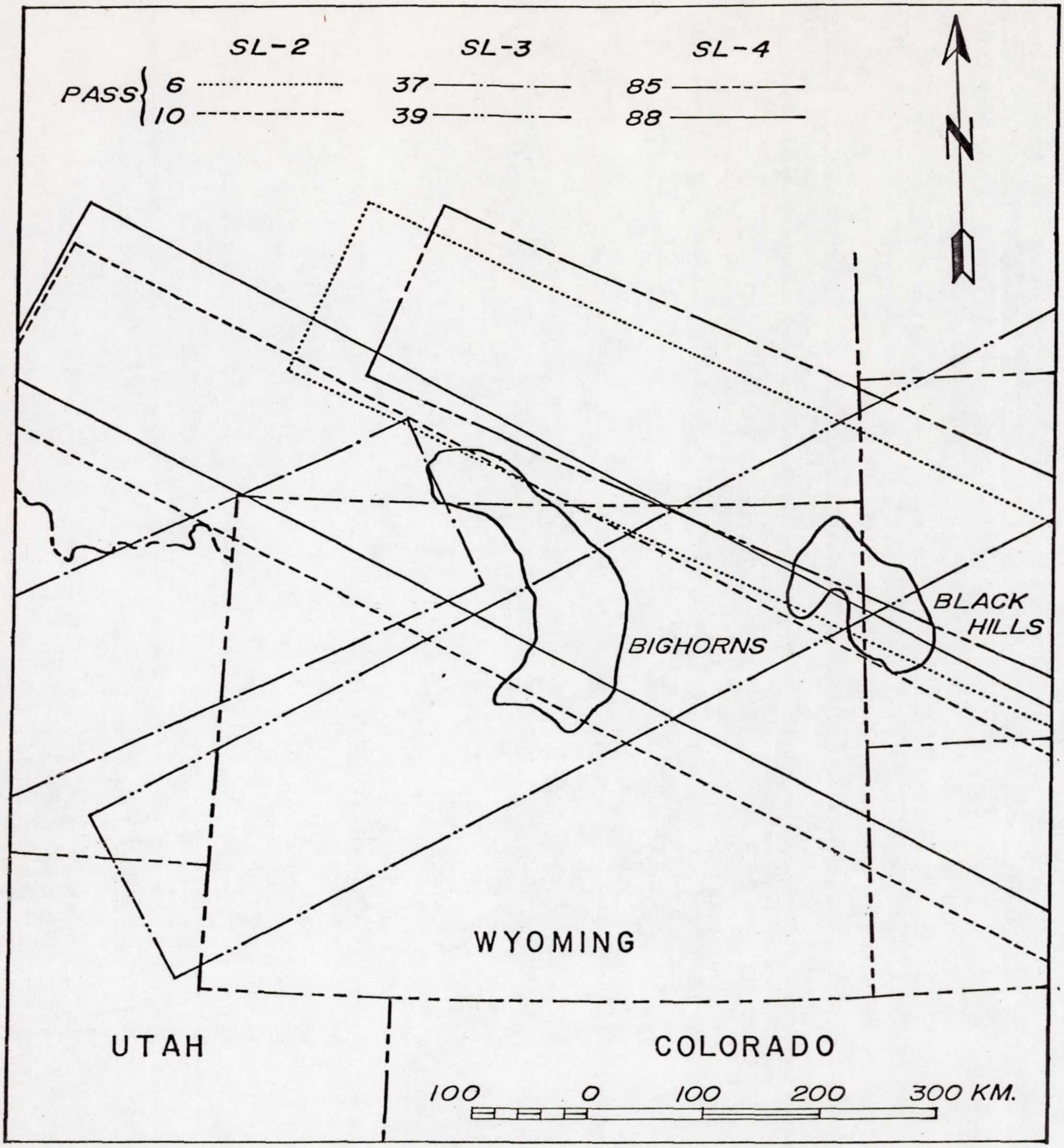


Figure 2. S190A Coverage.

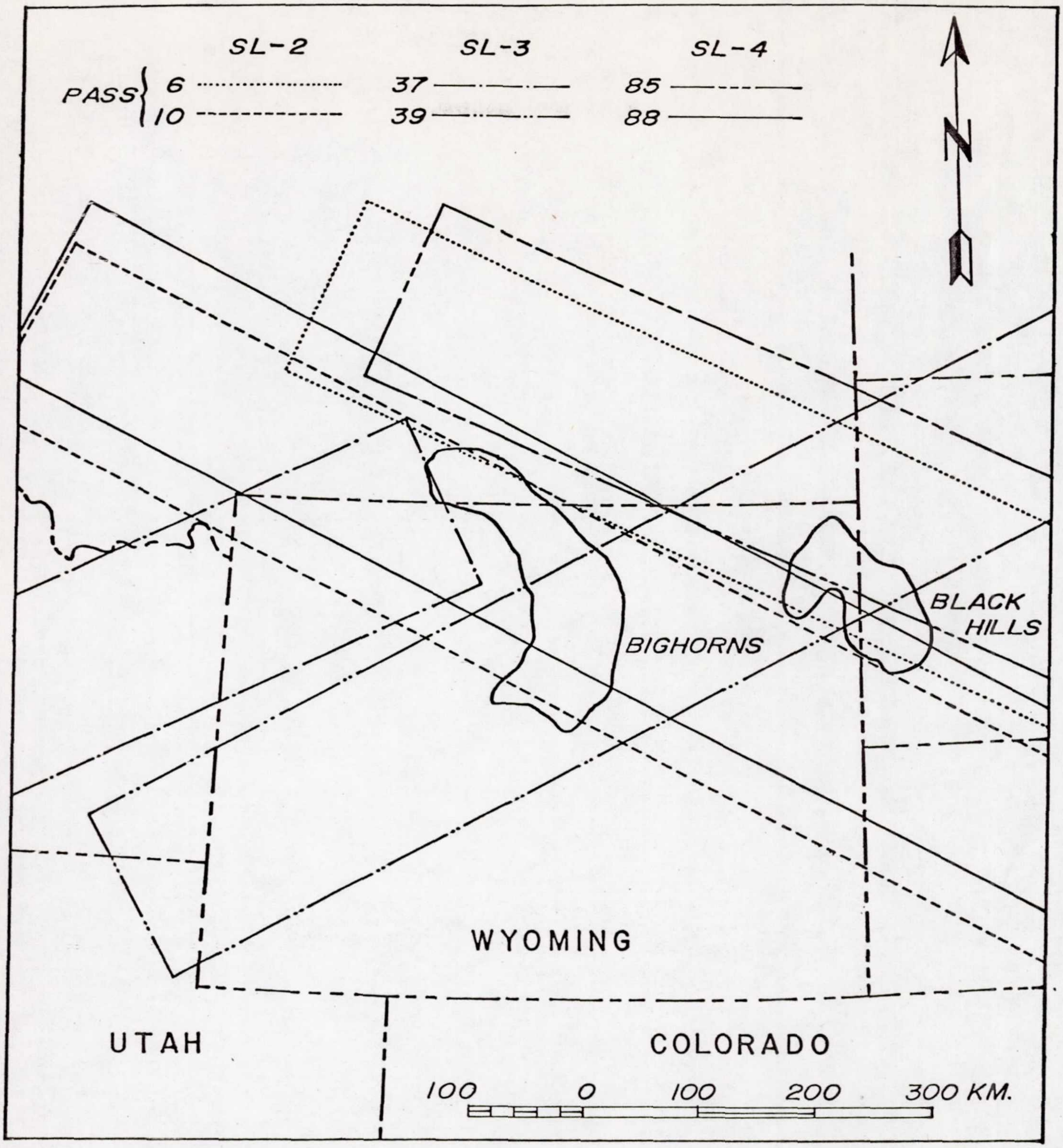


Figure 3. S190B Coverage.

patterns, linear maps) were prepared from selected frames. Image qualities were compared. Multispectral black and white 70 mm transparencies were viewed in an addicol viewer; this was discontinued because it provided no advantage over the color or color IR. Black and white prints were made in the darkroom facilities of the Department of Geology. A major improvement in the preparation of color prints was made as this report was being written. The Iowa Geological Survey Remote Sensing facility (now in the same building) purchased a color printer using the Cibachrome process which allows the preparation of color contact prints in about 12 minutes with excellent color fidelity. The main variable that has to be changed is exposure time in order to get the optimum darkness or (lightness). Because of the strong contrast between dark uplifts and lighter basins, one print does not provide best detail for both areas.

Interpretations were field checked in a number of areas that were chosen for graduate MS theses projects. Fracture measurements (foliation in the Precambrian of the Black Hills) were taken in many locations for correlation with drainage and linear overlays. Lithologic interpretations were compared with published maps or checked on the ground in a few places.

3.0 Results

3.1 Introduction

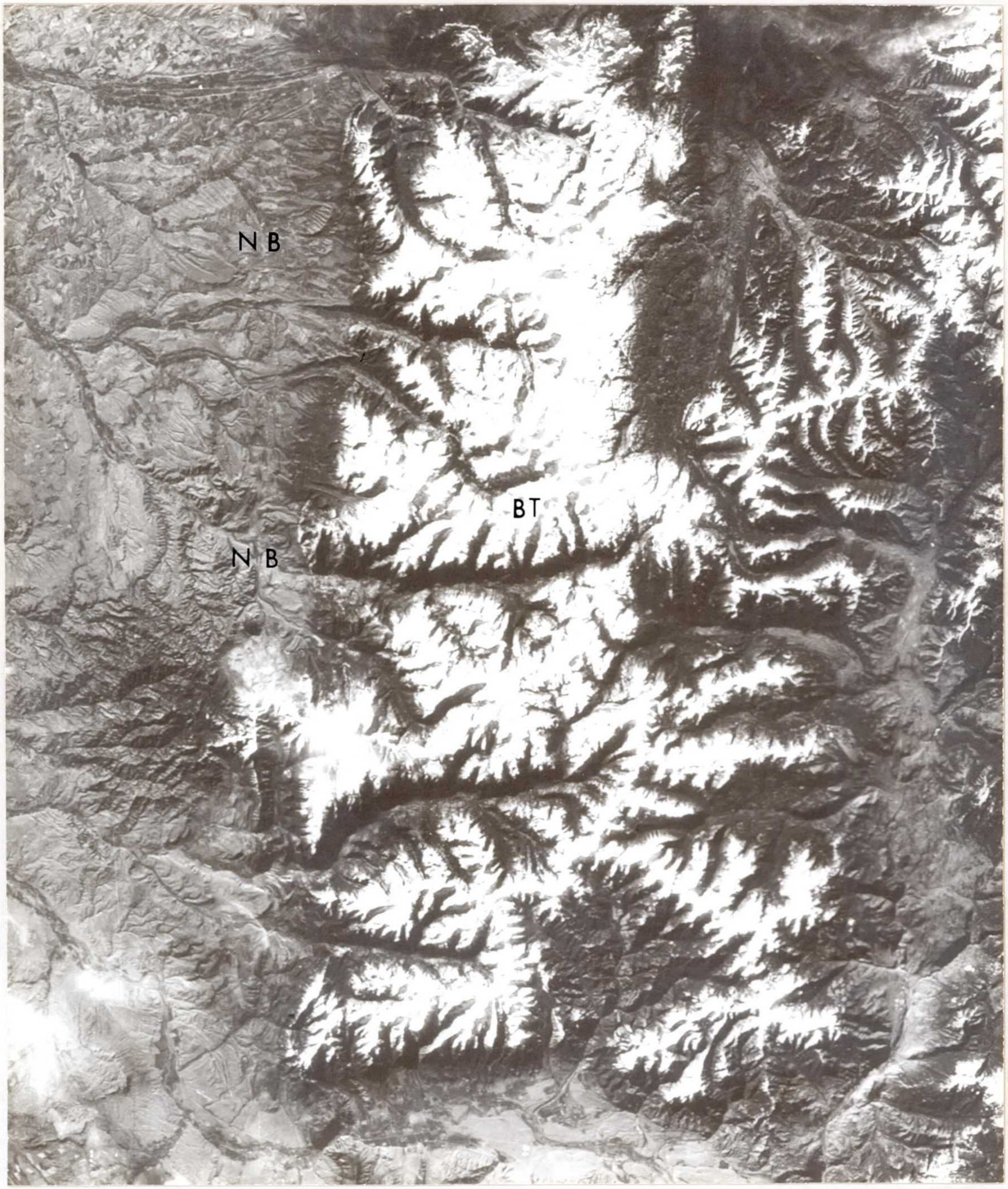
In spite of problems of incomplete coverage, there were still a large number of usable images. All were examined and summary notes made. Earlier quarterly reports contain summaries of imagery as it was reviewed. It was felt that the best evaluation could be presented by concentrating on a few specific areas. Five different areas are treated using S-190A and S-190B imagery. The different images are compared and their value in revealing geological information assessed. Examples from one of the RB-57 tracks are included. S-192 data is discussed in separate section. Finally, comparisons are made with ERTS imagery.

3.2 Beartooth Mountains - Nye-Bowler lineament

This area was imaged during SL-2 in the late spring. At this time of the year the lower areas are covered by a heavy growth of green grass. The green and red (Fig. 4) photographs tend to be quite dark as do the S-190A color (Fig. 6) and S-190B black and white (Fig.8). The black and white infrared (Fig. 5), however, shows better topographic detail and higher contrast and the Nye-Bowler lineament is more easily discerned. The dark images could be printed lighter but then the snow would be too bright. Actually, the black and white negative transparencies can provide better detail in the dark areas. By far the best image in this area is the S-190A Color IR (Fig. 7). The Nye-Bowler lineament appears as a narrow rectilinear zone of topographic linears. One would have a difficult time trying to outline distinctive lithologies although a wide variety of sedimentary, igneous and metamorphic rocks occurs here. The dendritic drainage and the joint pattern of the Beartooth would suggest an area of crystalline rocks. Although the Nye-Bowler lineament can be readily traced, it is not possible to determine what kind of slip predominates along this fault-controlled feature. Only hints of smaller faults and associated folds can be gained. Note that the lineament is masked by young alluvial deposits at its eastern end.

3.3 Northern end of the Big Horn Mountains

One SL-3, S-190B color image (Fig. 9) covered this area. S-190A coverage did not reach this far. This image is of particular interest



Kilometers
0 30

N

Figure 4. Nye-Bowler lineament (NB), Beartooth Mountains (BT)

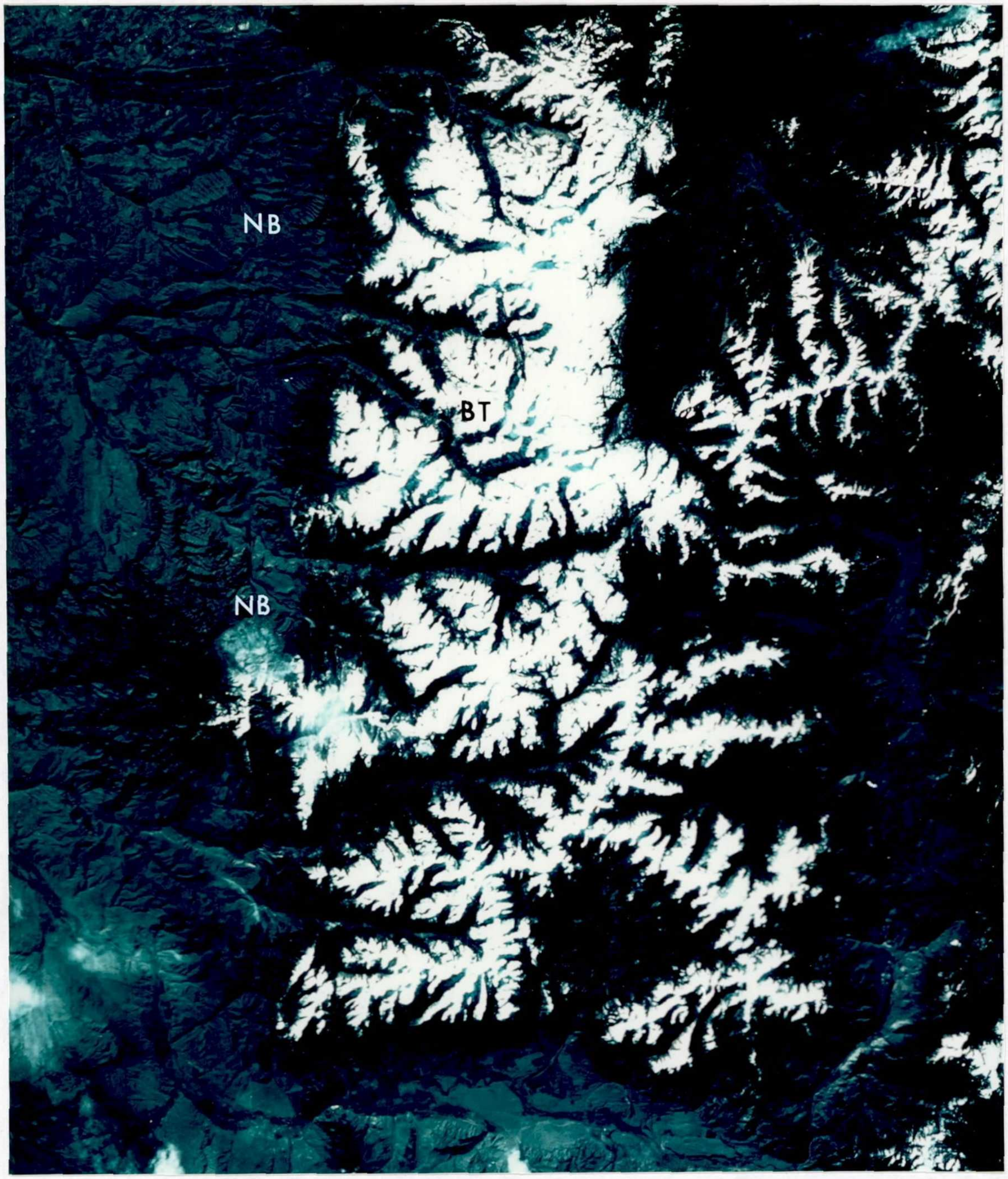
SL-2, S-190A, Red Band (.6-.7μ)
Pass no. 10; Roll no. 17; Frame no. 208.

Kilometers
0 30

N

Figure 5. Nye-Bowler lineament (NB), Beartooth Mountains (BT)

SL-2, S190A, Infra-Red Band (.7-.8μ)
Pass no. 10; Roll no. 13; Frame no. 208.



Kilometers
0 30 N

Figure 6. Nye-Bowler lineament(NB), Beartooth Mountains (BT)

SL-2, S190A, Color (.4-.7μ)
Pass no. 10; Roll no. 16; Frame no. 224.

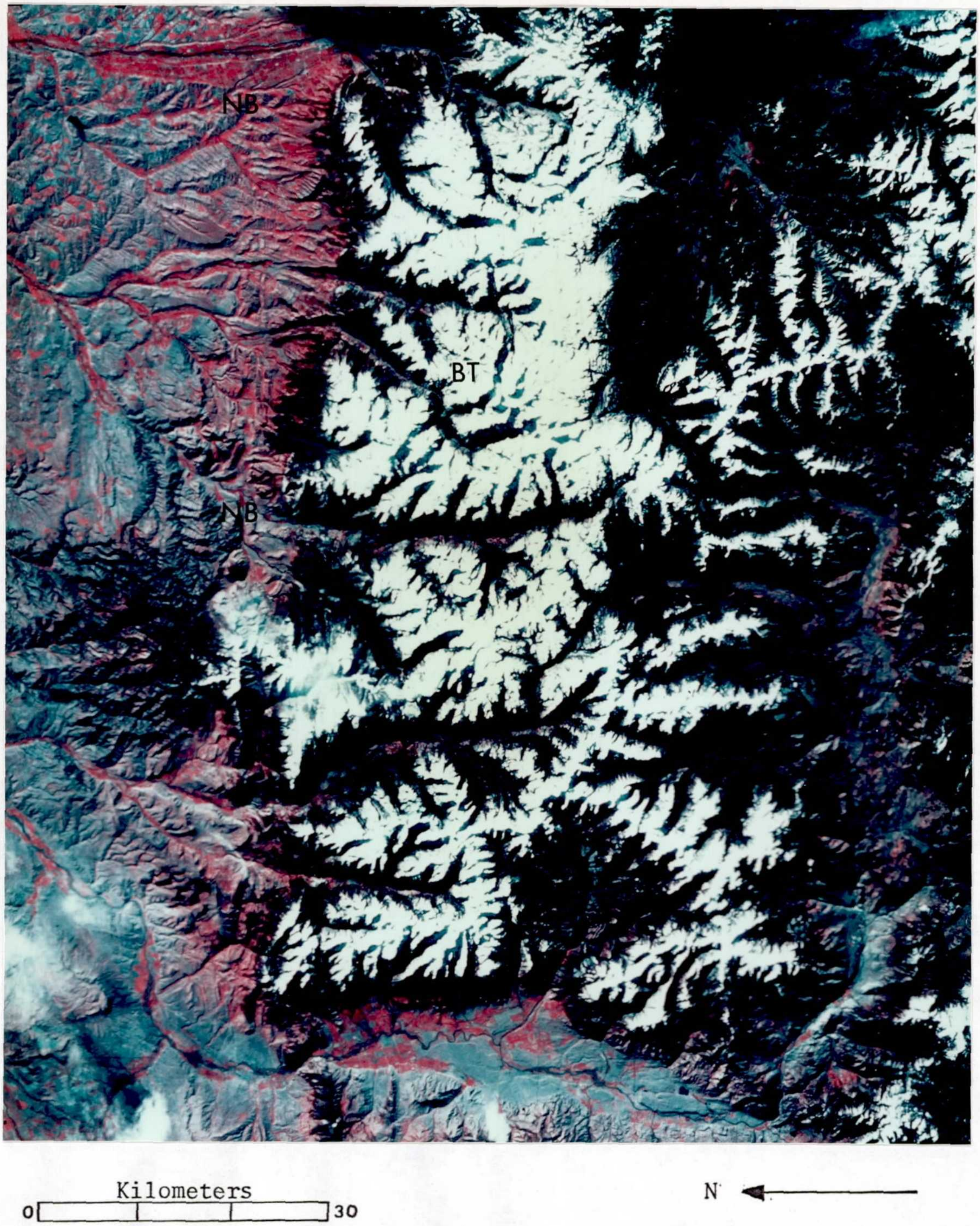


Figure 7. Nye-Bowler lineament (NB), Beartooth Mountains (BT)

SL-2, S190A, Color Infra-Red (.5-.88μ)
Pass no. 10; Roll no. 15; Frame no. 224)

Figure 8. Nye-Bowler lineament (NB), Beartooth Mountains (BT)

SL-2, S190B, High-Definition Black and White (.5-.7μ)
Pass no. 10; Roll no. 82; Frame no. 142.

Kilometers
0 20

N

Figure 9. Northern Big Horn - Pryor Mountains.
Overlay locates identifiable features.

SL-3, S190B, Color (.4-.7μ)
Pass no. 37; Roll no. 86; Frame no. 337.

Explanation of map symbols on the following page.

TABLE 4

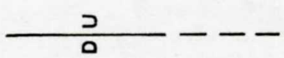
Explanation of Map Symbols for Figure 9.

NPF - North Pryor Fault
SC - Sage Creek Fault
CC - Crooked Creek Fault
DH - Dry Head Fault
SP - Sykes Spring Fault
FS - Five Springs Fault

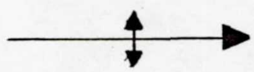
PM - Pryor Mountains
BHM - Big Horn Mountains
BHB - Big Horn Basin
PRB - Powder River Basin
CSB - Cookstove Basin
LSM - Little Sheep Mountain Anticline

Pp - Phosphoria FM. (Permian)
Tr-J - Triassic-Jurassic, undiff.
IP -P - Pennsylvanian-Permian, undiff.
Є.-M - Cambrian-Mississippian, undiff.

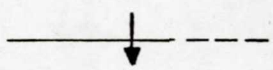
Contacts



High-angle Faults


Anticline


Syncline


Monoclines, arrow toward steep limb


Dip direction

(1) Fault or monoclinal linear not previously recognized.

because it provides an opportunity to check for evidence of an eastward extension of the Nye-Bowler lineament beyond the Pryor Mountains and across the northern Big Horns as postulated by some workers. Blackstone (1940) extended the Nye-Bowler into the Pryor Mountains to include the Sage Creek Fault and two shorter faults up to the north-south Dry Head-Sykes Springs faults which bound East Pryor Mountain. No definite sign of any extension of the Nye-Bowler lineament to the east can be seen. Careful study of larger scale photography in the area of the speculated extension confirmed that no such extension exists. This would indicate that speculative extensions of the Nye-Bowler lineament for hundreds or thousands of miles to the east are unwarranted. A more likely possibility that should be investigated on the ground is linear 1 on the overlay of Figure 9. This linear is well north of the usual extensions of the Nye-Bowler lineament. This linear appears to be a fault. If projected to the east, the line passes through the point where the Triassic (Chugwater)-Jurassic contact abruptly changes strike. The photograph shows a number of linears that correspond to monoclinal hinges, good indications of faults, traces of key beds that give dip directions, and some lithologic clues. Red beds of the Chugwater Formation (Triassic) can be seen in the west-central portion of the frame and less obviously along the east flank of the Big Horns. Here, as elsewhere in the project area, red beds are found in a number of other sedimentrary units so that red coloration as an indication of a particular stratigraphic unit must be used with caution.

The overlay annotates only those features that the PI could positively locate. Some known faults could not be identified. Broad categories of rock types can be delineated but most contacts, especially the Precambrian-Cambrian, are difficult to locate. Nevertheless, one can prepare an excellent preliminary map. Other detail could undoubtedly be added if the photograph could be used in the field. Unfortunately, much of the area is part of the Crow Reservation and not accessible for ground study.

3.4 Big Horn Basin - Big Horn Mountains

The photographs included here provide an excellent example for illustrating the general characteristics of each kind of film. They also show the difficulty of obtaining much of value over the major portion of the Big Horn Mountains. The green band (Fig. 10) shows fair contrast but detail is not as good as in the red owing to greater scattering by the atmosphere and by haze. Cloud shadows are not, however, as dark as in the other bands. The red band (Fig. 11) has the best contrast and highest resolution of the S-190A black and white films. Considerable structural detail can be seen in the Big Horn Basin. (note that because the basin is quite arid, even though late spring, the "green grass effect" noted in the moister Beartooth photographs is not a factor here). The Black and White IR (Fig. 12, 13) have lower resolution and are grainier although haze is less of a problem. S-190A color (Fig. 14A) provides excellent structural detail in the basin along with more lithologic clues. Like all the color on this track it is unfortunately quite dark, especially over the mountains (Fig. 14B). The S-190A Color IR (Fig. 15A,B) does not have as good resolution as the color film. It is quite blue and does not distinguish the red beds (as yellow) as it should. It does, however, show the prominent linears (Fig. 15B) in the southeast corner of the frame the best of all S-190A films. Note that although there is a sharp bend in the

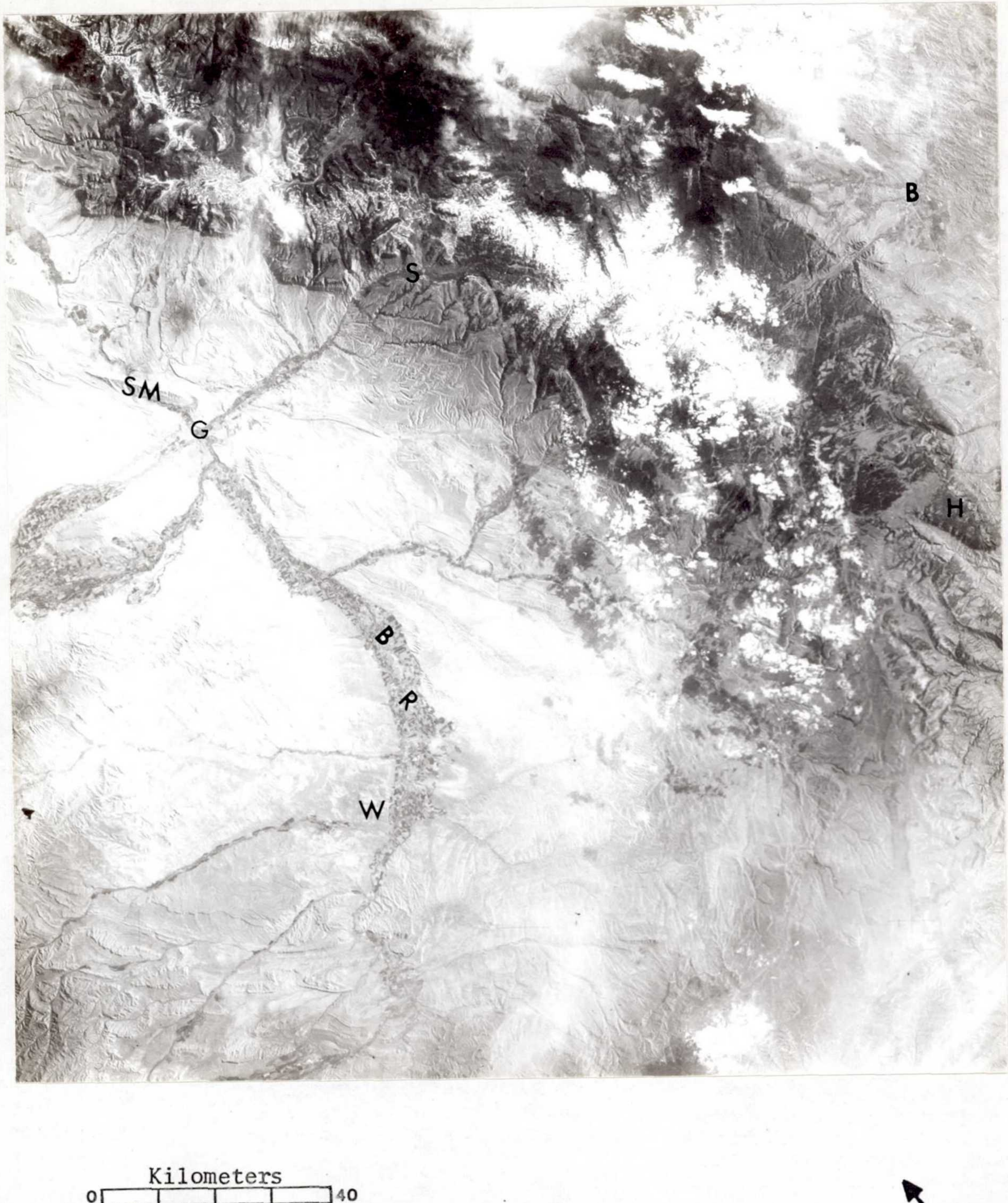
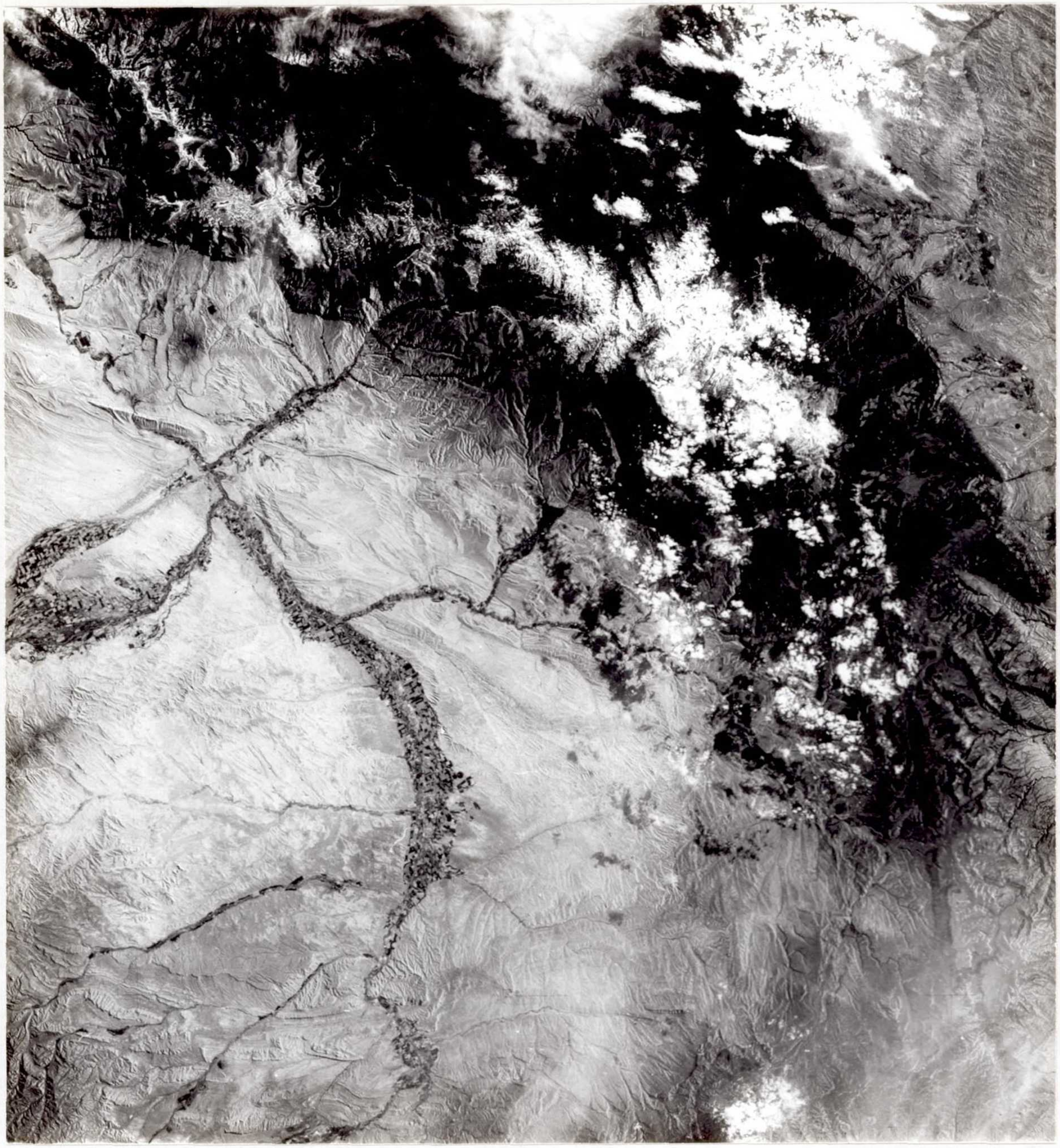


Figure 10. Big Horn Basin - Big Horn Mountains.

Big Horn River (BR), Horn area (H), Shell Canyon (S), Sheep Mountain Anticline (SM), Buffalo (B), Greybull (G), Worland (W).

SL-2, S190A, Green Band (.5-.6μ)
Pass no. 10; Roll no. 18; Frame no. 211.



Kilometers
0 40

N

Figure 11. Big Horn Basin - Big Horn Mountains.

SL-2, S190A, Red Band (.6-.7μ)
Pass no. 10; Roll no. 17; Frame no. 211.

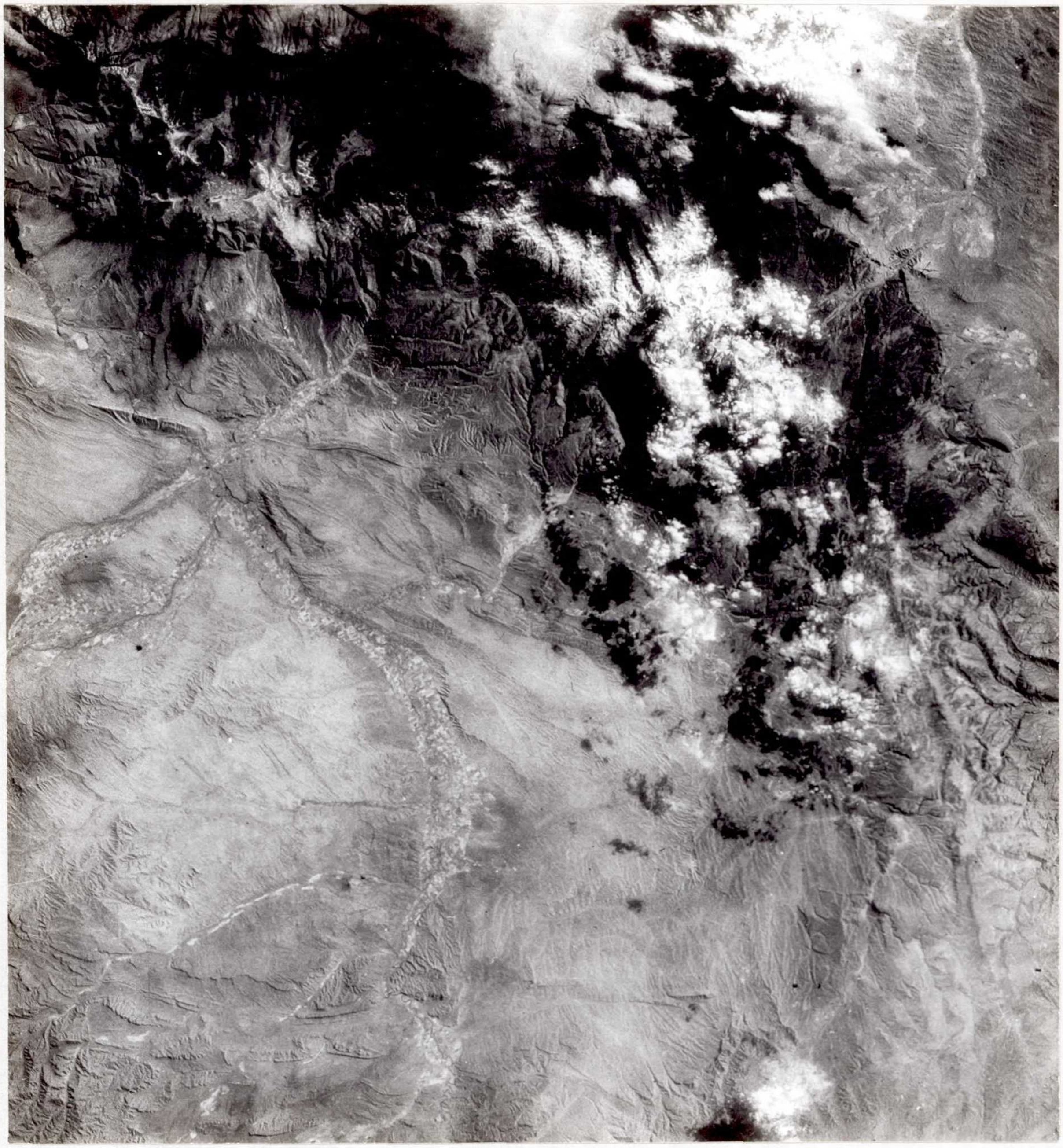


Figure 12. Big Horn Basin - Big Horn Mountains

SL-2, S190A, Infra-Red (.7-.8μ)
Pass no. 10; Roll no. 13; Frame no. 212.

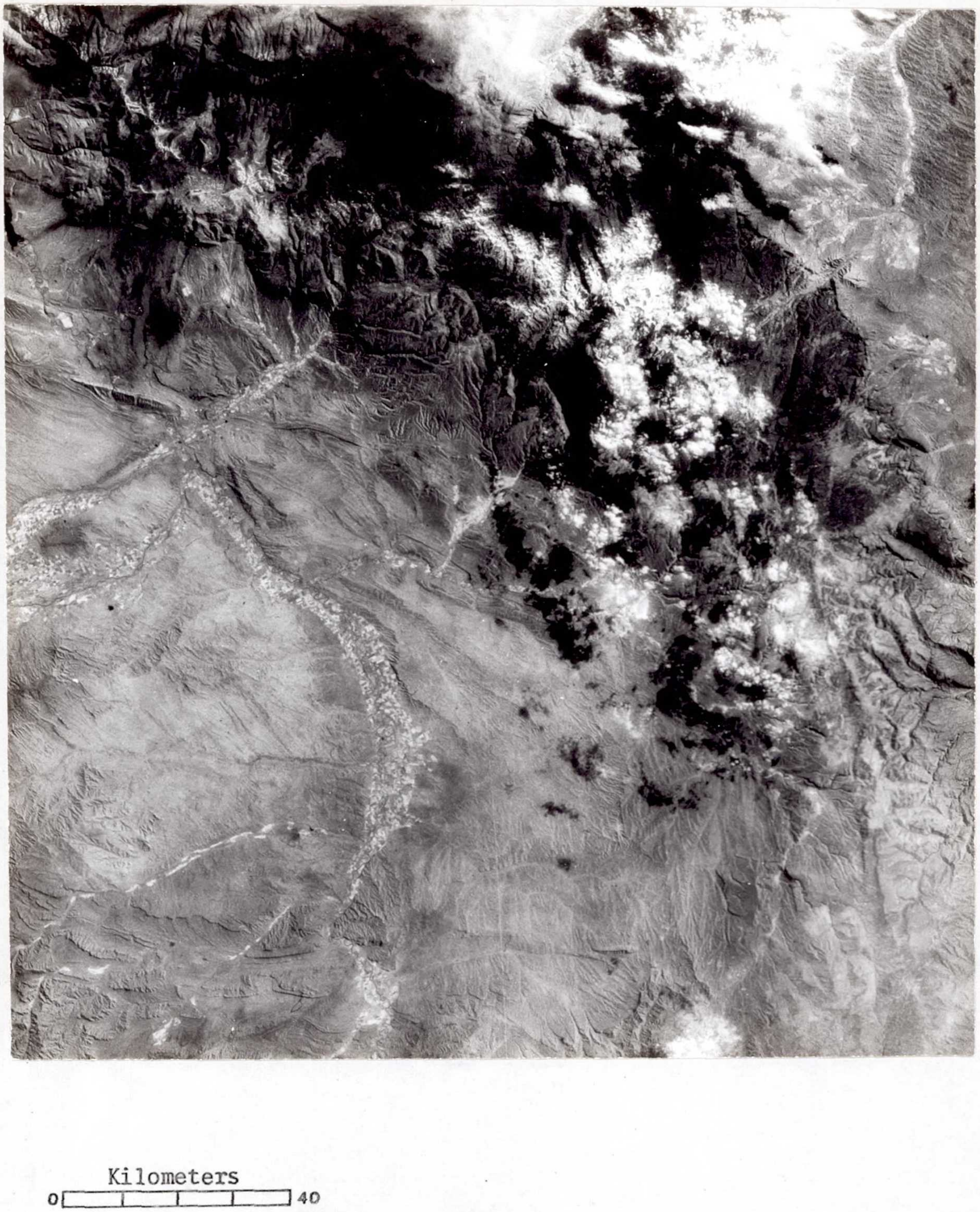


Figure 13. Big Horn Basin - Big Horn Mountains

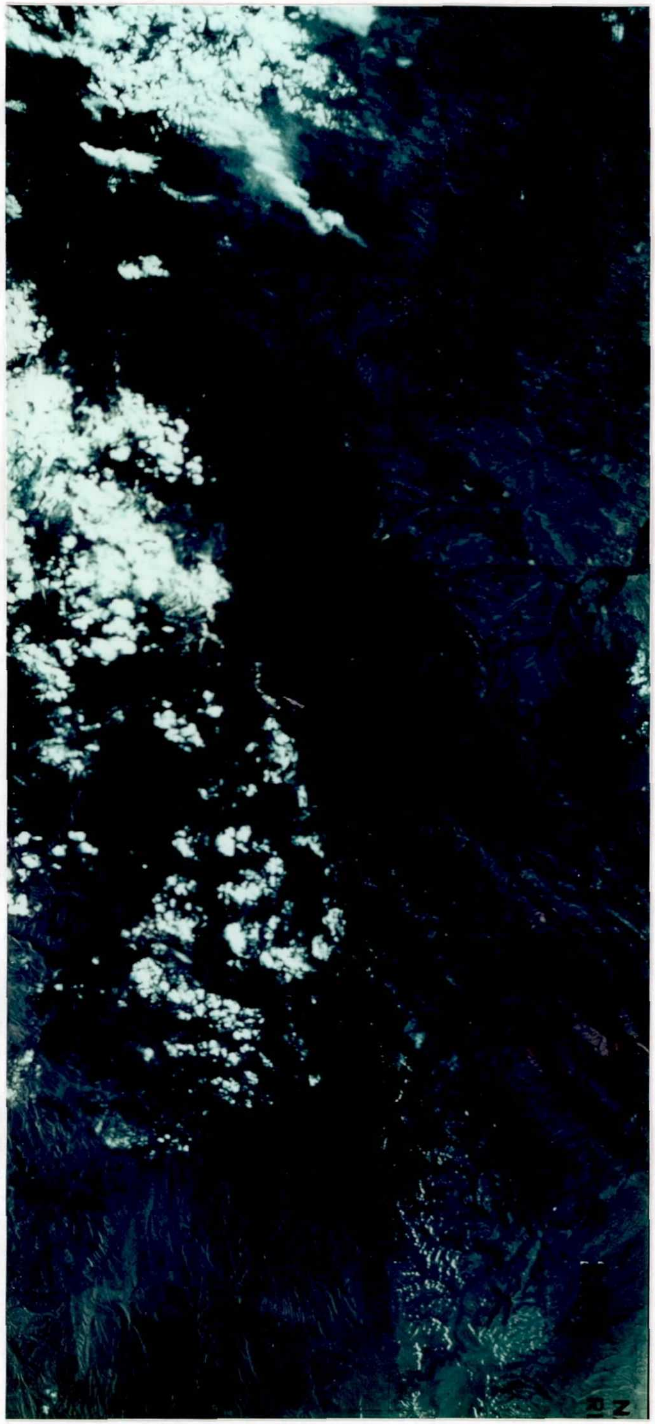
S1-2; S190A, Infra-Red (,8.-9μ)
Pass no. 10; Roll no. 14; Frame no. 212

Kilometers
0 30

N

Figure 14-A. Big Horn Basin

SL-2, S190A, Color (.4-.7μ)
Pass no. 10; Roll no. 16; Frame no. 228.

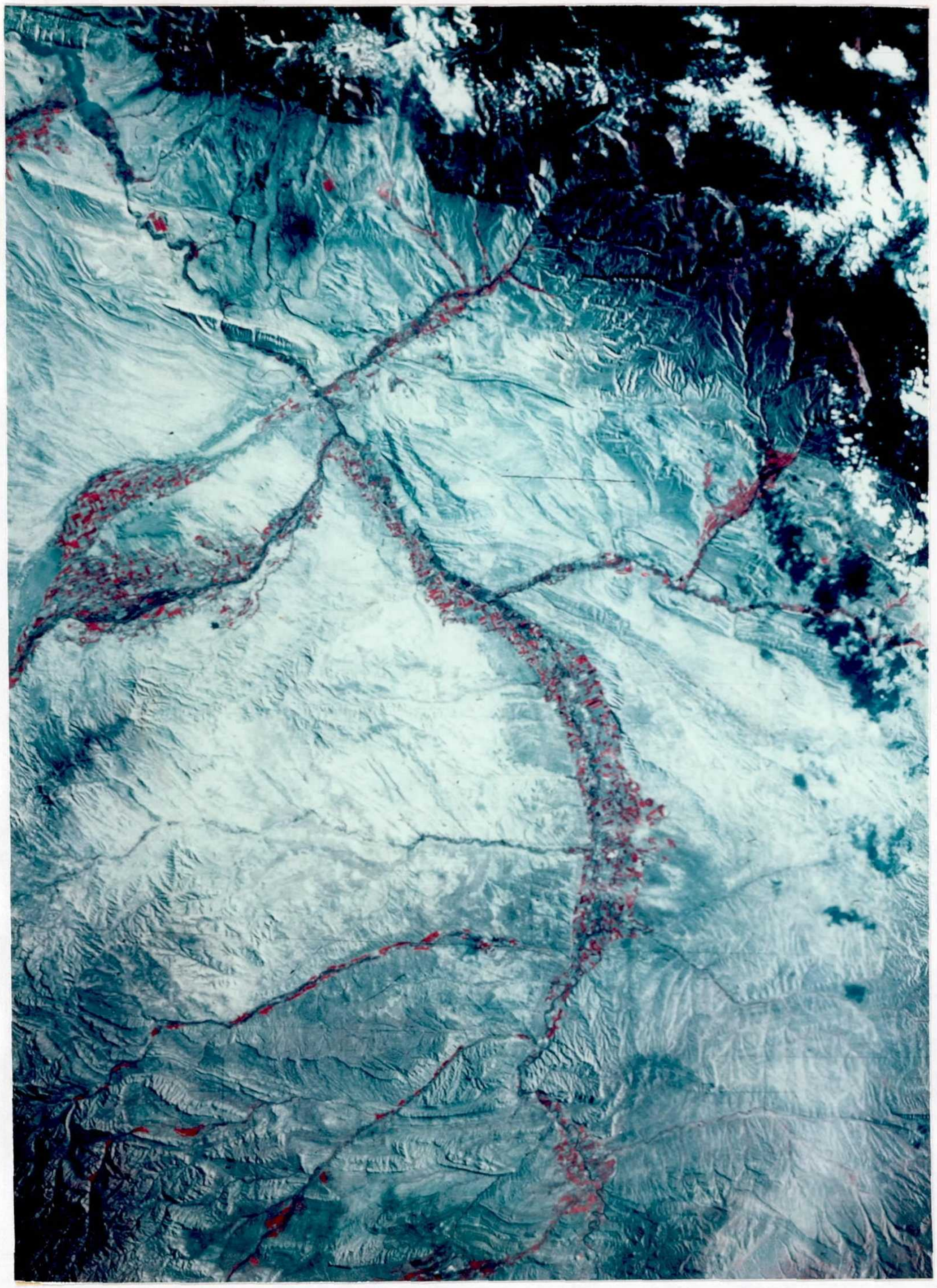


Kilometers
0 30

N

Figure 14-B. Southern Big Horn-Owl Creek Mountains

SL-2, S190A, Color (.4-.7μ)
Pass no. 10; Roll no. 16; Frame no. 228



Kilometers

0 30

Figure 15-A. Big Horn Basin

SL-2, S190A, Color Infra-Red (.5-.88μ)
Pass no. 10; Roll no. 15; Frame no. 228.

N

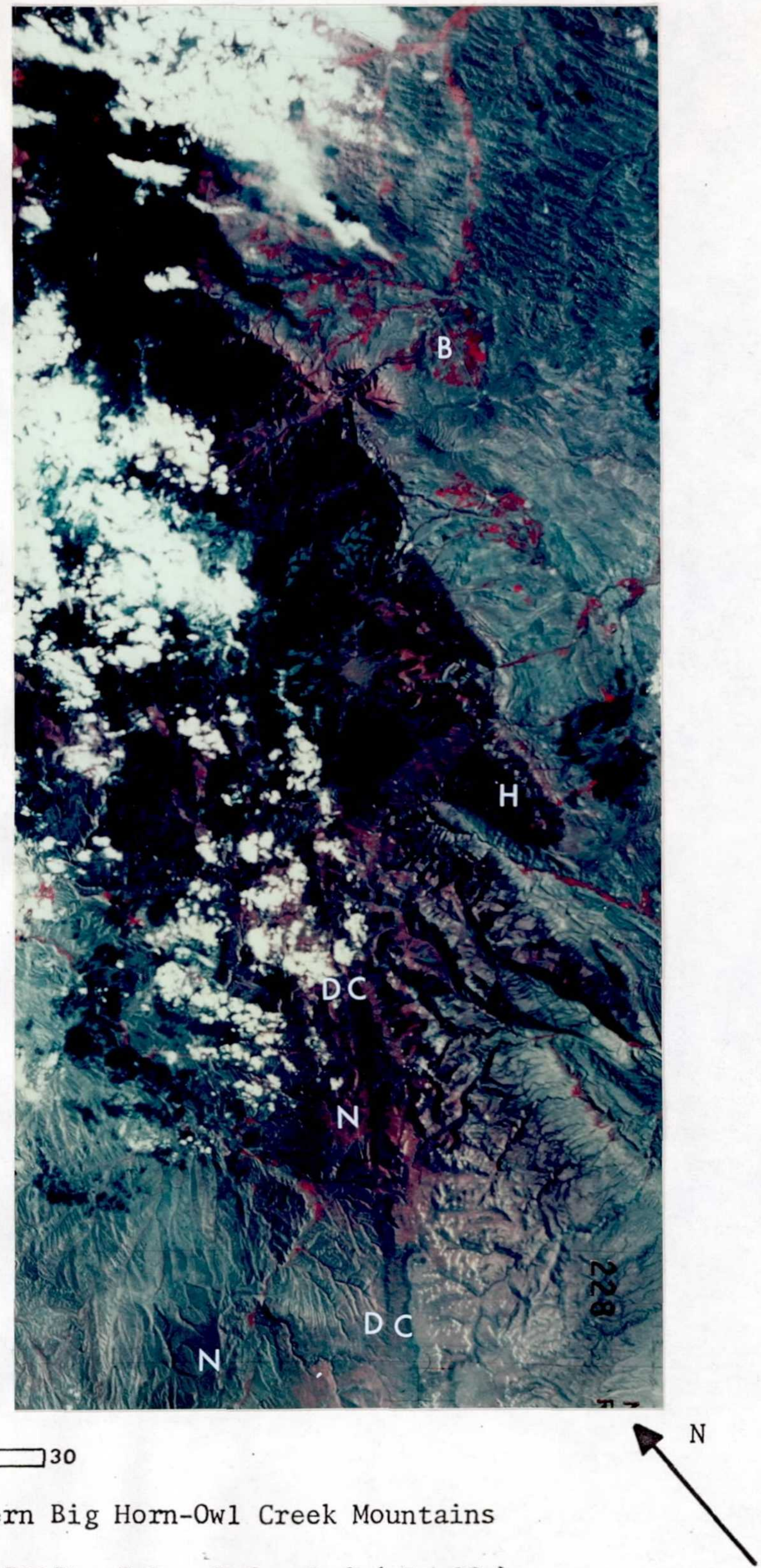


Figure 15-B. Southern Big Horn-Owl Creek Mountains

SL-2, S190A, Color Infra-Red (.5.-88μ)
Pass no. 10; Roll no. 15; Frame no. 228.

TABLE 5

Explanation of symbols on Figure 15-B.

B	-Buffalo
H	-Horn area
DC -DC	-Deep Creek Fault
N-N	-Nowood Fault

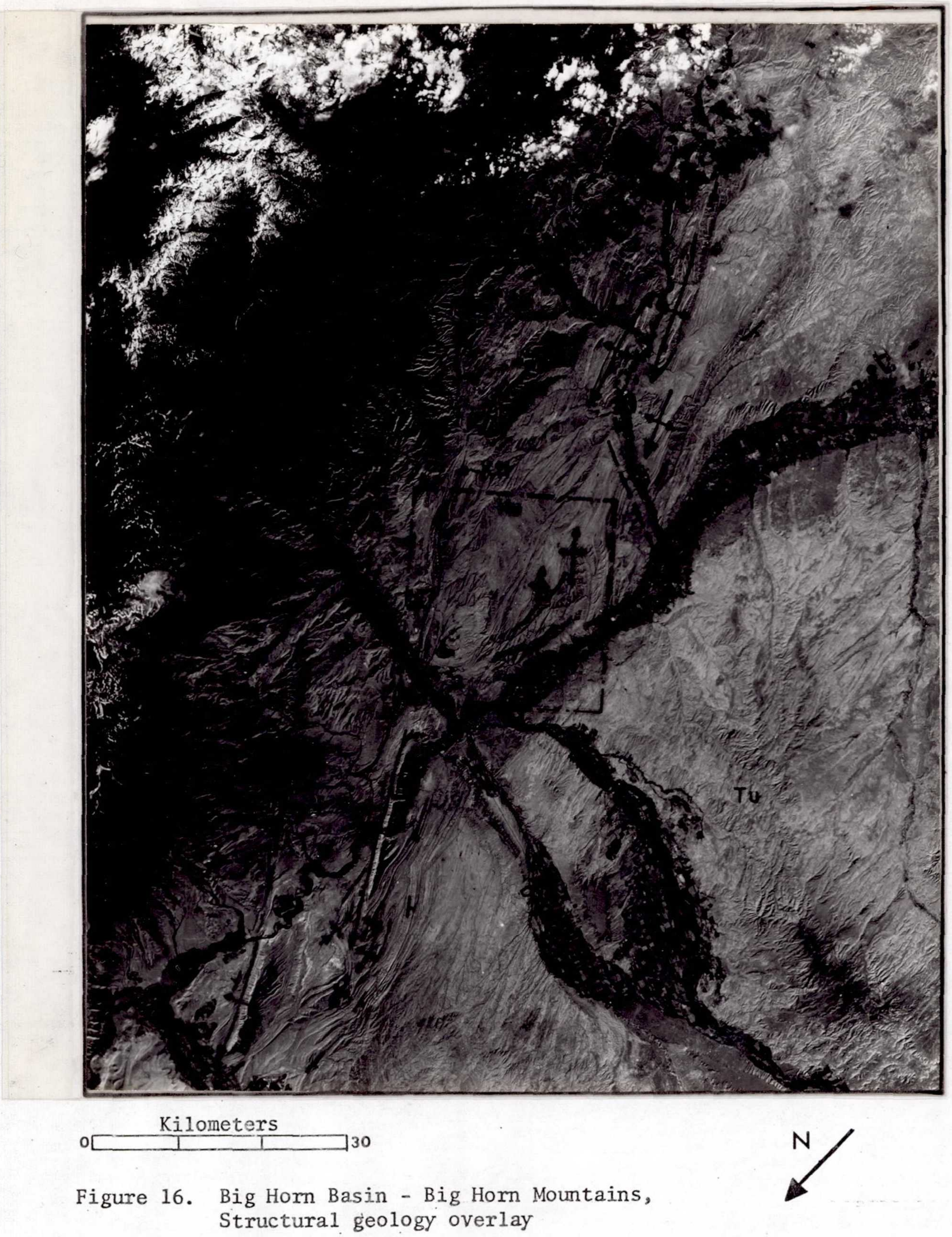


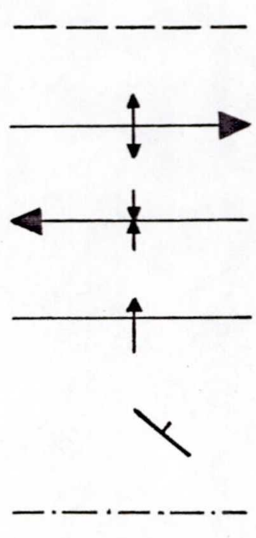
Figure 16. Big Horn Basin - Big Horn Mountains, Structural geology overlay

SL-2, S190B, High resolution Black and White (.5-.7μ); Pass no. 10; Roll no. 82; Frame no. 144.

TABLE 6

Explanation of Map Symbols for Figure 16.

G	- Greybull
B	- Basin
M	- Manderson
H	- Hyattville
SC	- Shell Canyon
LSM	- Little Sheep Mountain
SM	- Sheep Mountain
Kft	- Frontier Sandstone ridge
Ku	- Cretaceous, undifferentiated
Tu	- Tertiary, undifferentiated



Possible faults

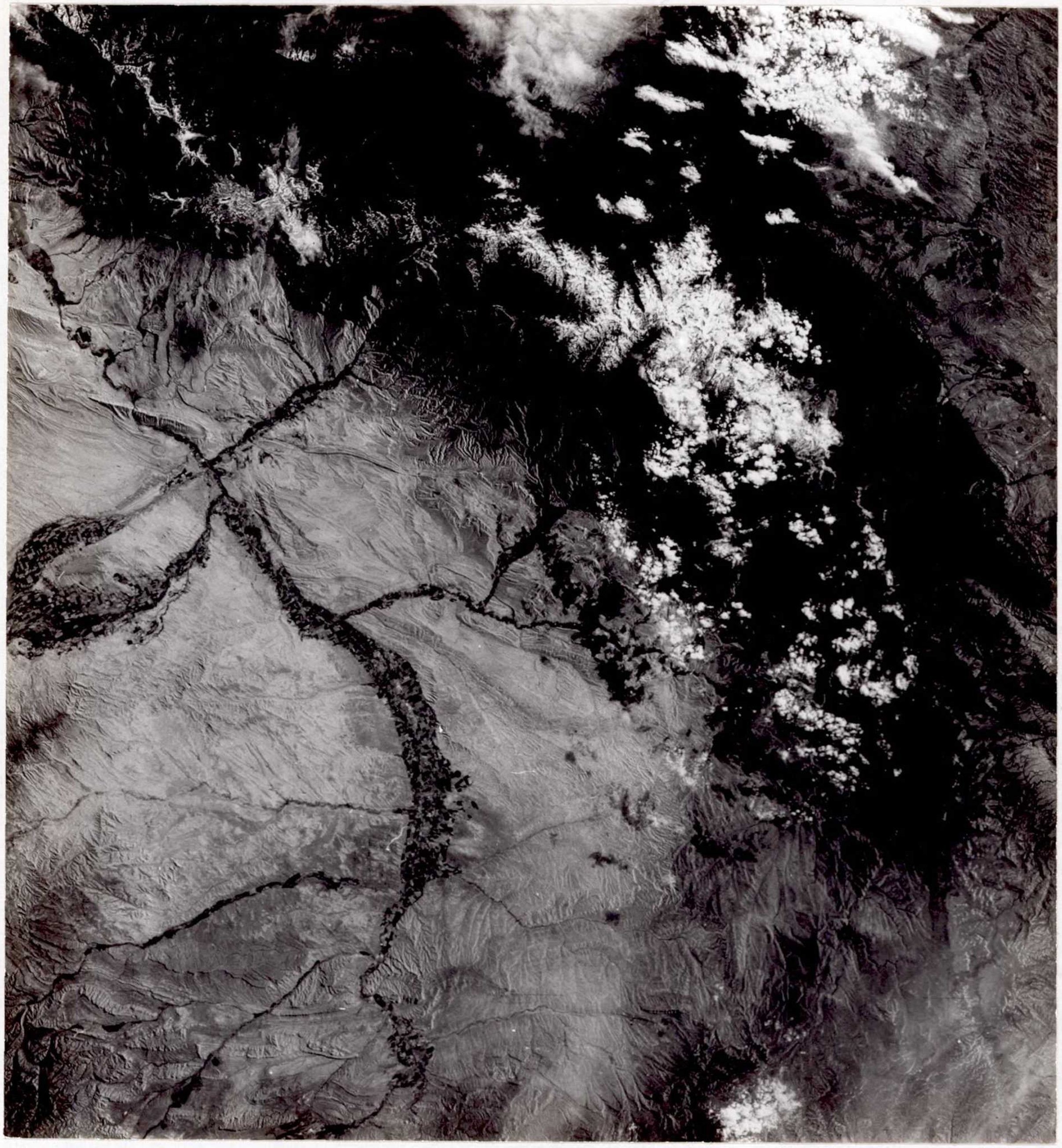
Anticlines

Synclines

Monoclines

Dip directions

Area covered by RB-57 photo, (Fig. 27).

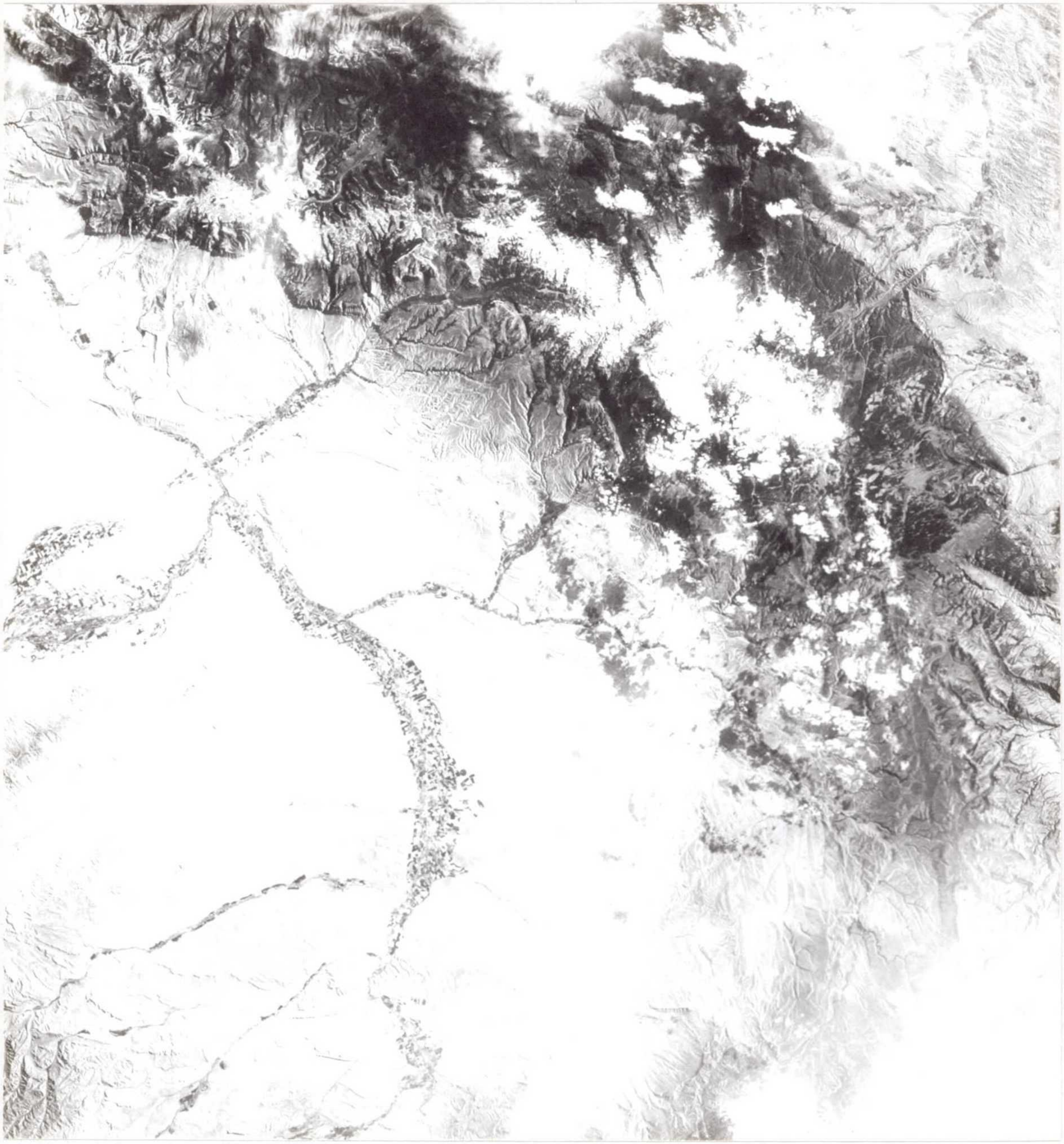


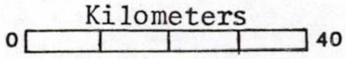
Kilometers
0 40

N

Figure 17. Big Horn Basin - Big Horn Mountains.
Basin enhanced by longer exposure time.

SL-2, S190A, Red Band (.6-.7μ)
Pass no. 10; Roll no. 17; Frame mo. 211





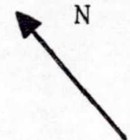


Figure 18. Big Horn Basin - Big Horn Mountains.
Mountain uplift enhanced by shorter exposure.

SL-2, S190A, Red Band (.6-.7μ)
Pass no. 10; Roll no. 17; Frame no. 211.

trends of the Mesozoic units at the northeast corner of the Horn area, no offset is visible at this point which is just east of the last mapped displacement along the Tensleep Fault. The S-190B high resolution black and white (Fig. 16) provides the best base for mapping structure.

As noted earlier, exposure times in printing can be varied in order to best enhance areas of quite different photo character. The red band is used to show how the basin can be enhanced (Fig. 17) or, conversely, the mountains (Fig. 18).

3.5 Black Hills

The Black Hills uplift provides a real challenge to the geologist who wants to map the major rock units. The uniform forest cover on the uplift masks a number of different rock types - Precambrian metamorphics and granite of the core, overlying Paleozoic and flanking Mexozoic sediments and Tertiary intrusions. The Precambrian rocks are the hosts for almost all the metallization and of valuable pegmatites; however, they crop out over a relatively small area of the uplift. If one were planning an exploration for minerals in an area such as this it would be helpful if the Precambrian target could at least be approximately delimited so that the area for more detailed work could be cut down. We utilized both ERTS-1 and SKYLAB imagery and found that drainage and linear overlays revealed differences in intensity and in pattern between the Precambrian rocks and the overlying Paleozoic rocks (Hoppin, et al, 1975).

SKYLAB imagery, though not covering the entire uplift, provides a slightly more detailed and accurate representation of drainage than ERTS because of larger scale, better resolution and stereo overlap. Black and White IR offered the best format for preparing overlays even though it has poorer resolution than the other films, because of the suppression of the dark tones of the forest and enhancement of the drainage (Fig. 19). In Figure 20 and 21, the location of the contact between the core of Precambrian rocks and the flanking cover of Paleozoic rocks as interpreted compares quite favorably with that shown on the latest geologic map. Drainage in the schists has a strong NNW trend which is the same as a very prominent axial plane cleavage; a less prominent WNW trend parallels a good fracture set. A more angular pattern roughly outlines the Harney Peak granite. It was found that by proper processing the green band was quite good. S-190B color is dark and a drainage overlay is not as good as off the IR.

3.6 Owl Creek Mountains

Though partially cloud and haze covered, this area is one of the most interesting ones structurally. Tappmeyer (1974, p. 21) in a study utilizing satellite imagery and SLAR in the southwest Big Horns - southeast Big Horn basin was able to outline some broad tonal units that conform to groupings of geologic formations. He was able to delineate 5 units - (1) Precambrian, (2) Cambrian through Pennsylvanian, (3) Permian through lower Jurassic, (Gypsum Springs), including the red beds of the Chugwater (Triassic), (4) Cretaceous (Mesa verde-Lance) and (5) Tertiary.

S-190B (Fig. 22) is particularly good for outlining structure and mapping some lithologic units. S-190A color (Fig. 23) is almost as good, but is a bit dark. S-190A Color IR is also dark and quite blue; it does discriminate the red beds a little better than that in Fig. 15A. This scene is a good example where SKYLAB can provide, through its large area

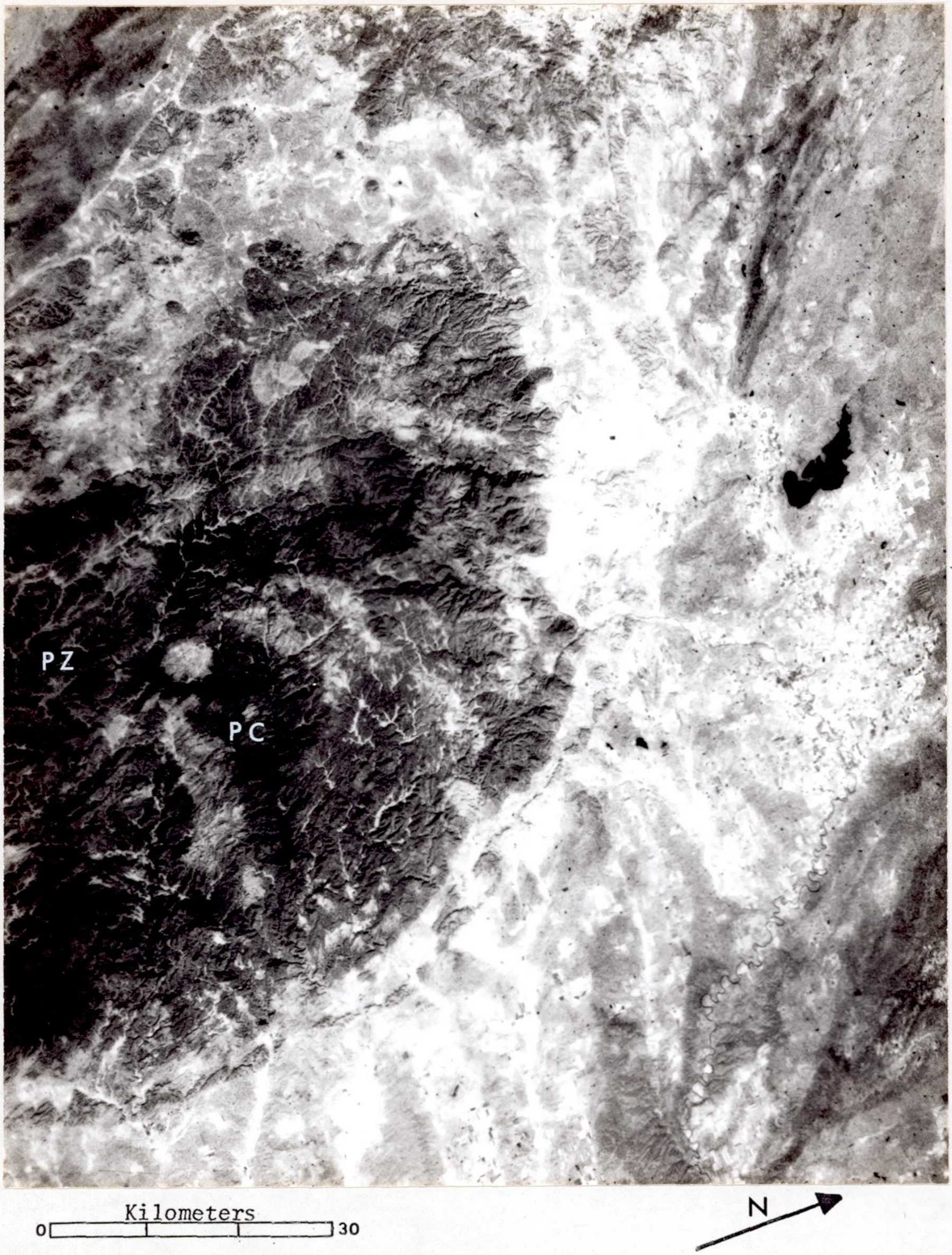


Figure 19. Northern and Central Black Hills.
Precambrian (PC), Paleozoic (PZ).

SL-2, S190A, Infra-Red (.8-.9μ)
Pass no. 6; Roll no. 8; Frame no. 113.

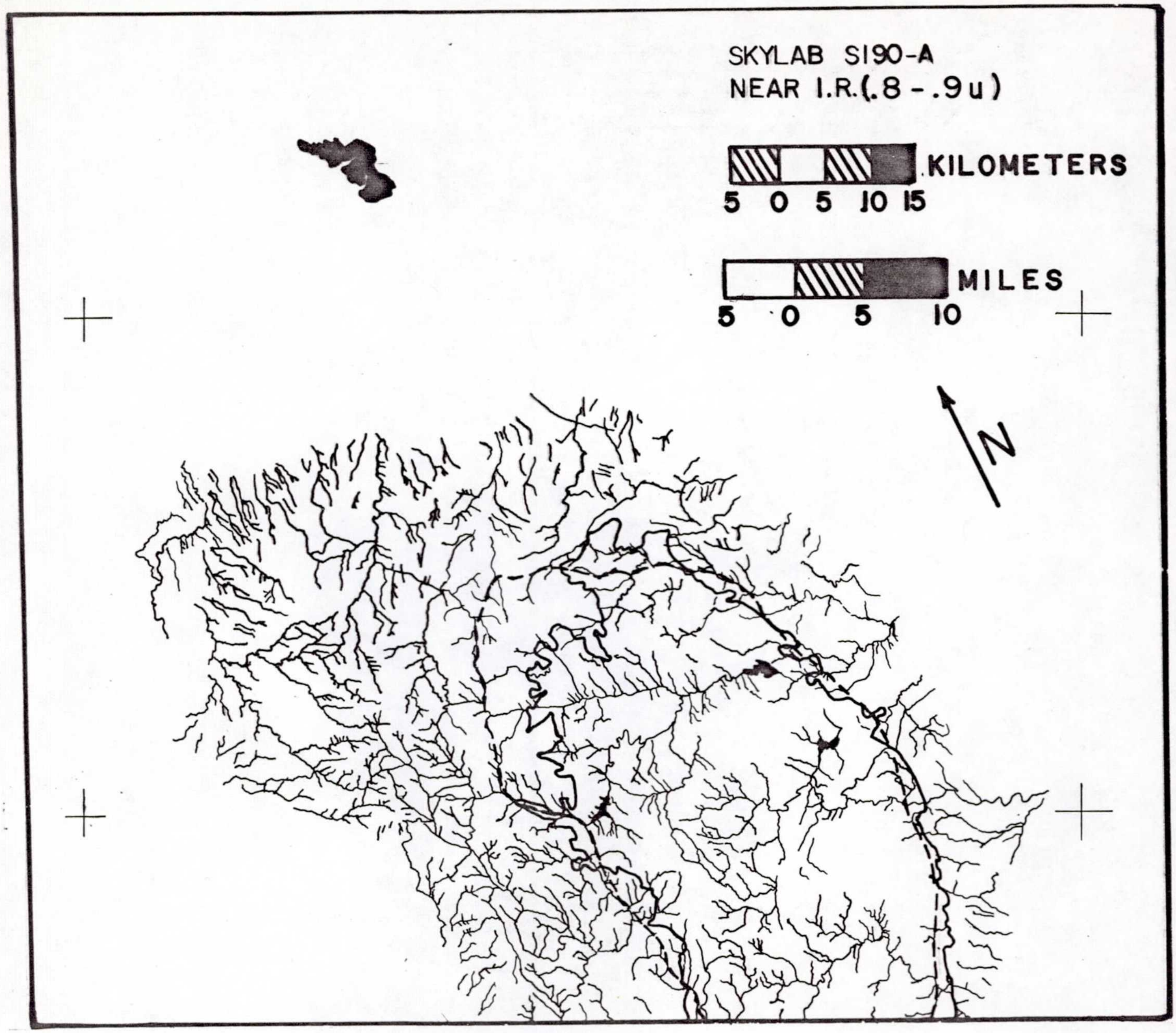


Figure 20. Drainage overlay of Black Hills.
Precambrian-Cambrian contact.
– – – – – – – – – – Interpreted
———————————— Mapped (Kleinkopf and Redden, 1975)

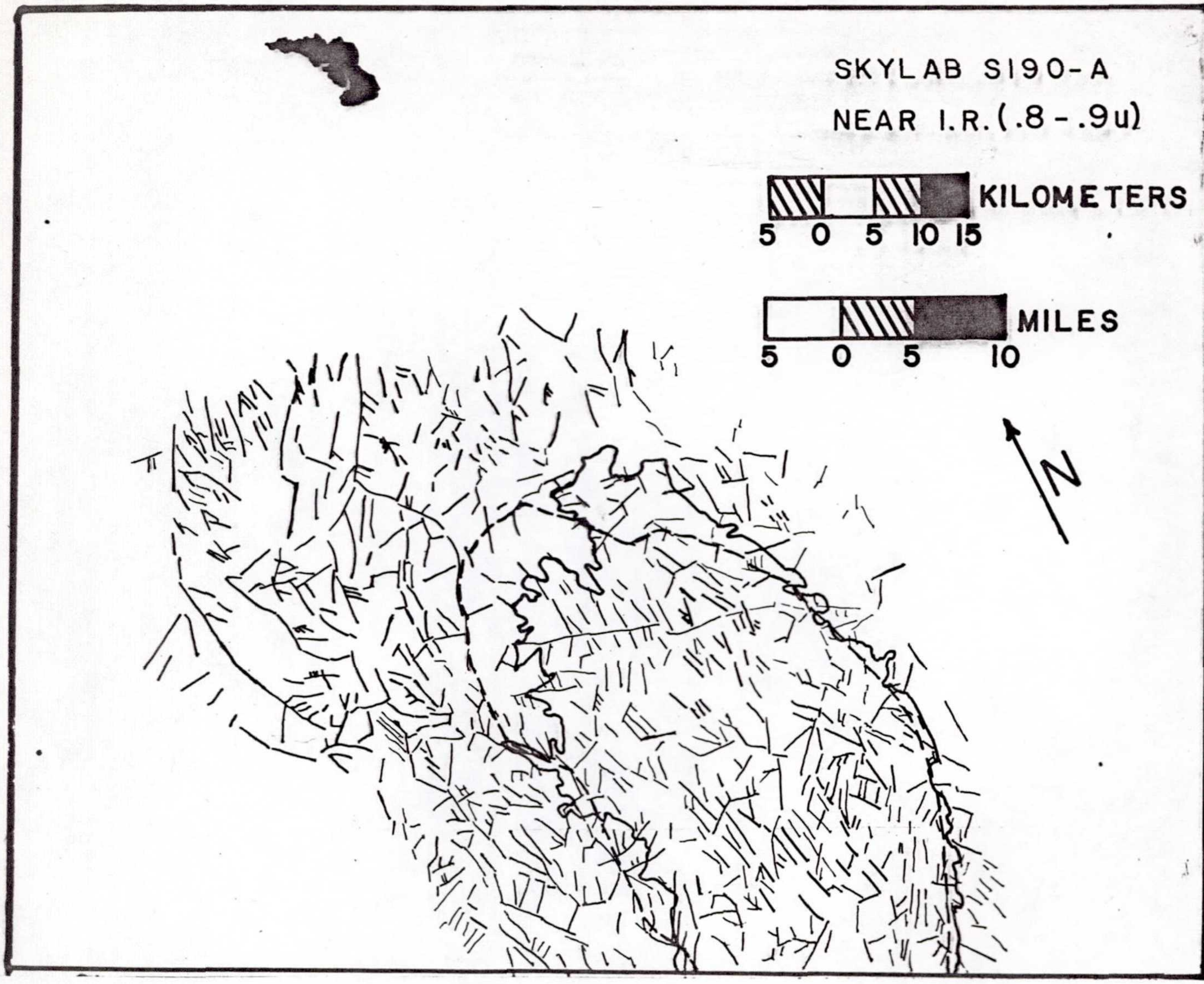
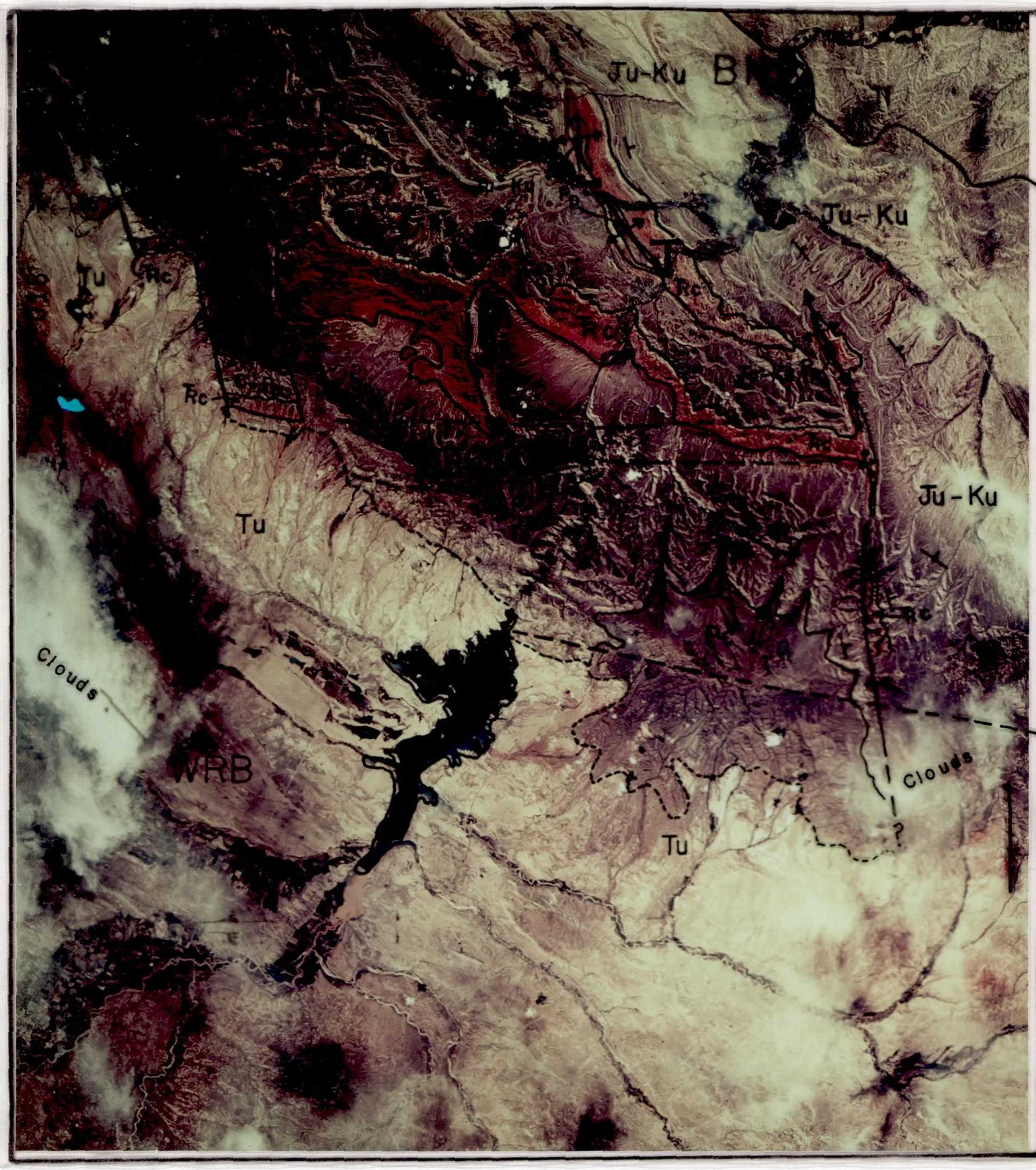


Figure 21. Linear overlay of Black Hills Precambrian -Cambrian contact
——·——Interpreted
————Mapped

covered, along with good resolution, some valuable structural information. The overlay on Figure 22 is a geologic sketch map. The Chugwater Formation can be readily mapped. The Owl Creek Mountains trend east-west, bounded on the south by an upthrust and associated faults (not traceable on SKYLAB). Cutting obliquely across the uplift are several ENE trending linears which have not been previously recognized. One first observed on ERTS imagery has been called the Bates Creek linear (Fig. 23) at its east end. It appears to cut through the Precambrian window and reappears on the south flank of the range north of the Boysen dam. Although there is no evidence of major younger faulting, it does pass into and follow a wide zone of strong layering and foliation in the exposed Precambrian rocks having the same trend. A case for reactivation along an old Precambrian zone of weakness seems compelling. More field study is needed on this and the other parallel features. Several NNW trending lines of folds, faults and monoclines also cut across the range. A portion of the eastern one was mapped in the field during the summer of 1975 by Caldwell. Reconnaissance by Caldwell and Hoppin of the southern end of this lineament reveals highly complex structure at the southern flank of the range. This same lineament appears to terminate the east-west trending lineament through Thermopolis; this supports the earlier conclusions from study of ERTS imagery that the proposed extension of the Thermopolis lineament to the east is not valid.

3.7 S-192 Data

Screening film of channels 2, 7, 11 was received for all three missions. SL-2 data was of little use because of small scale and poor quality. SL-3 imagery is in a larger scale format than SL-2 and is much better quality; channels 2 and 11 give the best contrasts and complement each other.



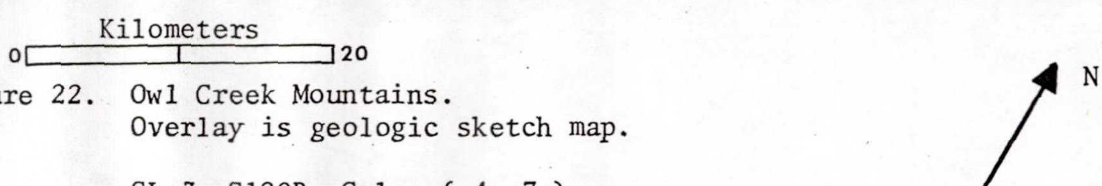


Figure 22. Owl Creek Mountains.
Overlay is geologic sketch map.

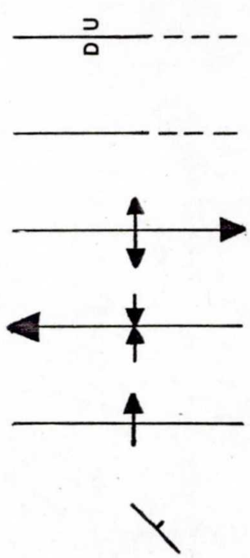
SL-3, S190B, Color (.4-.7μ)
Pass no. 39; Roll no. 88; Frame no. 18.

TABLE 7

Explanation of map symbols for Figure 22.

OCM	=	Owl Creek Mountains
BHB	-	Big Horn Basin
WRB	-	Wind River Basin
BR	-	Boysen Reservoir
T	-	Thermopolis

Tu	-	Tertiary, undifferentiated
Tf	-	Fort Union (Paleocene)
Ju-Ku		Jurassic-Cretaceous, undifferentiated
Trc	-	Triassic, Chugwater Formation
Pp	-	Permian, Phosphoria Formation
C-Pp		Cambrian to Permian units
P	-	Precambrian



High-angle faults

Linears

Anticline

Syncline

Monocline

Dip direction

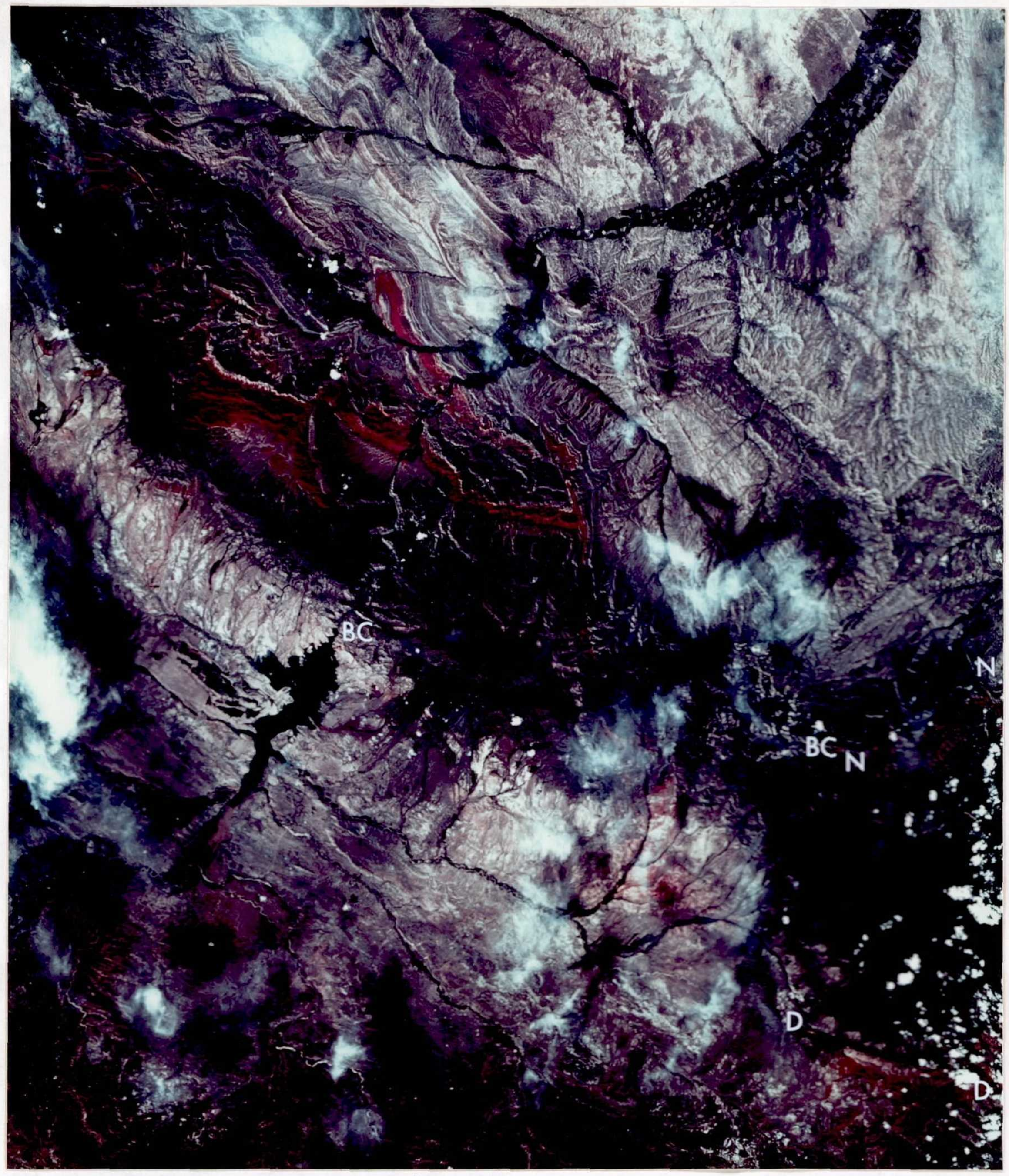


Figure 23. Boysen Reservoir - Owl Creek Mountains

Dry Fork Fault (D - D), Nowood Fault (N - N).
Bates Creek Linear (BC - BC).

SL-3, S190A, Color (.4-.7μ)
Pass no. 39; Roll no. 40; Frame no. 207.

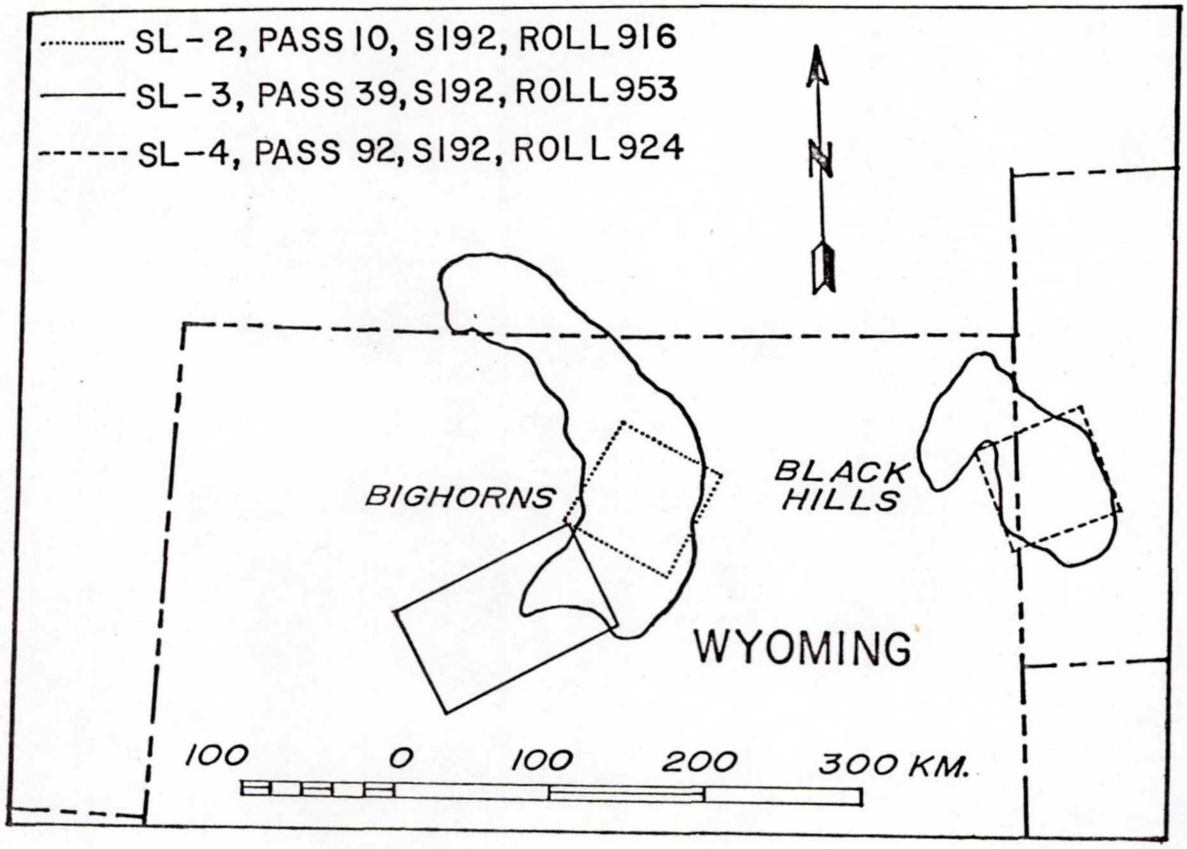


Figure 24. Coverage of Precision Corrected S192 Data.

This imagery does not provide nearly as much detail as the S-190A and B systems but, nevertheless, the larger scale structures are visible and one can easily view the whole track at once.

Two precision corrected segments from SL-2 and SL-3 were obtained. The SL-2 segment covered the southern end of the Big Horns. This was not much improved over the screening film. Scan line noise is still bothersome. Serious scattering in the low wavelengths make these of little use. Quality in the red band is improved but still not as good as the comparable photography.

The SL-3 segment over the Owl Creek was the best S-192 product received. Bands 3 and 4 (.52-.61μ), though dark, shows resistant units. The best of all bands such that some structure can be interpreted. Band 11 (1.55-1.75μ) is lighter and shows linears the best along with better haze penetration. Band 10 (1.20-1.30μ) is the best single band as it combines the best of the shortwave bands with that of the near IR bands.

A number of combinations of S-192 bands were tried on the additive color viewer, but the results were not nearly as good as the color and color IR camera imagery.

Two examples of the night time thermal IR band are of interest. Fig. 25 is over the southern Big Horns. Although there is considerable noise and cloudes, the Deep Creek fault (DC) is visible, perhaps because of higher moisture along the fault zone. Fig. 26 covers the west central part of the Black Hills. The Fanny Peak lineament (Shapiro, 1971) stands out sharply; in this case it marks a sharp topographic and vegetational boundary. A surprising feature of this image is the contrast between the area of exposed Precambrian rocks and the area underlain by younger sedimentary rocks.

Figure 25. Southern Big Horn Mountains
Deep Creek Fault (DC)

SL-2, S192, Precision Corrected Thermal
Band 13, Pass no. 10; Roll no. 916

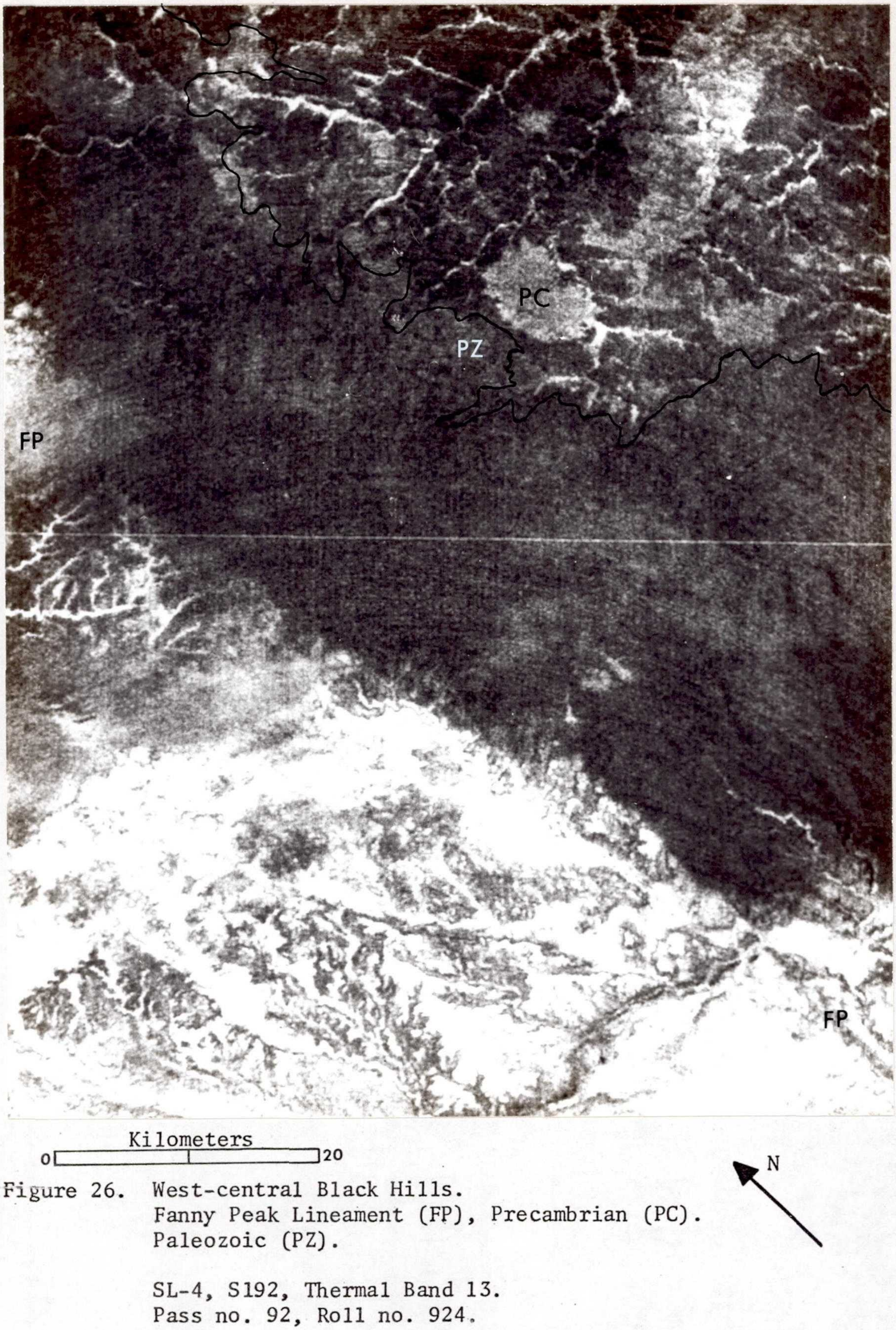


Figure 26. West-central Black Hills.
Fanny Peak Lineament (FP), Precambrian (PC).
Paleozoic (PZ).

SL-4, S192, Thermal Band 13.
Pass no. 92, Roll no. 924.

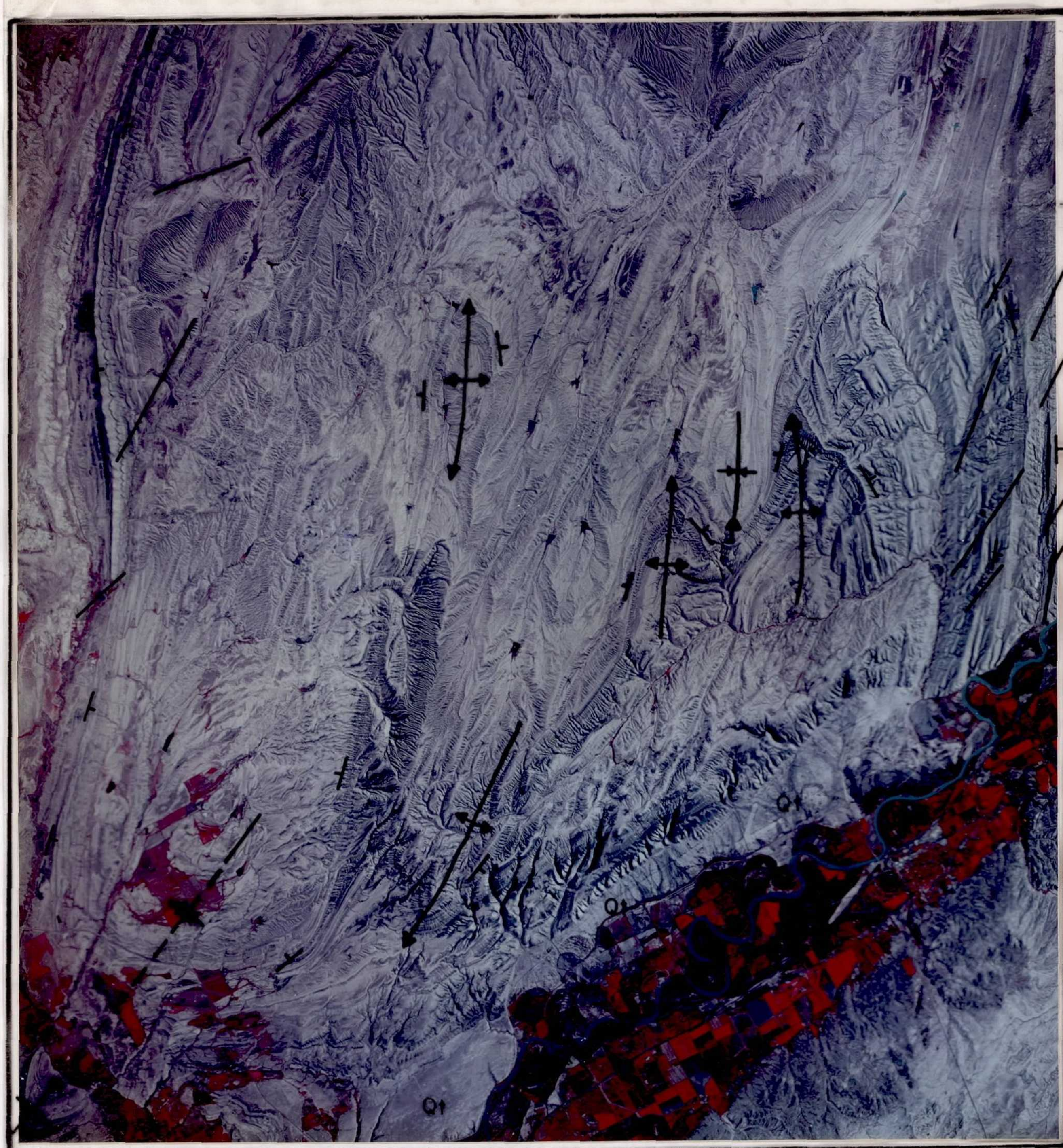
3.8 RB-57 underflights

Color IR take from RB-57 aircraft was used to provide a comparison with corresponding SKYLAB tracks; times were not synchronous. The imagery in clear portions is superb and allows for considerable structural mapping. Figure 27 in the Big Horn Basin covers a small portion of the single SKYLAB frame (Fig. 16). As might be expected the additional detail revealed at this scale indicates several more folds and a number of small faults than can be seen on the SKYLAB frame.

Another RB-57 frame covers the Precambrian window and a portion of the Owl Creek Mountains. Although hazy, it still reveals considerable detail of layering and fracturing in the Precambrian rocks. RB-57 imagery in cloud free areas of the Powder River Basin revealed no apparent mappable units or structure. Drainage is beautifully developed; future plotting of drainage patterns may help yield clues for buried folds. Scattered pale yellow areas in the southern Powder River Basin may be due to exposures of red clinker beds in the Wasatch (Eocene) formation.

3.9 Comparison with ERTS imagery.

ERTS imagery has the main advantage of eventually being able to provide cloud free coverage of this area at various times of the year. It does not, of course, have the resolution of the SKYLAB imagery. Hence, the best ERTS imagery does not reveal as many of the folds known to be exposed in the Big Horn basin. SKYLAB imagery does show almost all of the mapped anticlines in the region covered. There is no doubt that if it were possible, complete, cloud free coverage of an area by the S-190B color or high resolution black and white film would provide the ideal photomapping base combining adequate resolution (at least for structural work) and large area of coverage in one image.



Kilometers
0 4

N

Figure 27. Big Horn Basin - Structural Overlay. Check Fig. 16 for location. RB-57, Color Infra-Red (.5-.88μ), Frame 135-0065. Basin (B), Terrace (Qt), Alluvium (Qal), Frontier Sandstone ridge (Kft).

U D - - Faults

Anticline

Dip direction

Syncline

4.0 Summary and Conclusions

Because of gaps in areal coverage, cloud and snow cover, the original objectives could only be partially accomplished. The study of lineaments across the Big Horn Mountains was particularly limited. A good opportunity was provided, however, to look for a postulated extension of the Nye-Bowler lineament beyond its presently mapped location in the Pryor Mountains. No evidence could be found on an excellent S-190B color image of any continuation to the east across the northern end of the Big Horns or beyond into the Powder River Basin. Similarly no extension of the east end of the Tensleep Fault into the Powder River Basin could be detected. In the Owl Creek Mountains several ENE trending linears (or perhaps better called lineaments) cutting obliquely across the range were noted. These do not appear to have been noted by previous workers. At least three NNW linears also cross the range. Two west of Wind River Canyon are known faults, one at least an upthrust. The easternmost is an anticline at its northern end. The central portion was mapped on the ground in the summer of 1975 and is found to be a monocline. The southern portion is very complex where it intersects the east-west south flank structure. The SKYLAB imagery emphasized more than ever the complexity of the Owl Creek Mountains.

Most anticlines in Paleocene and older sedimentary rocks in the Big Horn Basin are quite clearly recognizable considerably better than on ERTS. Although marker horizons and distinctive photogeologic units can sometimes be mapped in a conventional photogeologic manner, these don't commonly coincide with the geologists' stratigraphic formations. Where good ground truth is available or field checking can be done it is possible to locate geologic formations on SKYLAB imagery.

The forest covered Black Hills uplift offers an especially strong challenge for the photointerpreter attempting to distinguish areas of Precambrian rocks with their economic potential from overlying Paleozoic rock and Tertiary intrusives. It was shown that differences in drainage and linear patterns allowed the core of Precambrian rocks to be rather well outlined on SKYLAB as well as ERTS imagery. This would help the exploration geologist by narrowing his target.

All S-190A and S-190B imagery was useful. Transparencies, both positive and negative, were the starting point. Positive prints could be varied in tone and tonal contrast by variations in exposure times. Different images highlight different things depending upon time of year, vegetation types and amounts, rock types and structure. If one had to select one system, it would be the S-190B, either color or high resolution black and white with complete stereoscopic coverage. Almost as good is S-190A color and the black and white red band.

In spite of problems of gaps in coverage and weather conditions, there is no question that SKYLAB imagery is a most effective tool for mapping of structural features, folds and high angle faults and lineaments, in much of this region. Areas of younger Tertiary cover are still a problem, because it masks older structures. Thrusts and upthrusts are much more difficult to recognize, as they often are even on low-altitude photography. If this were a geologically unknown region, this imagery would provide an excellent base of geologic information for guiding subsequent ground studies. The SKYLAB system combines large areal cover with quite reasonable resolution.

An added bonus has been the educational use of SKYLAB imagery. Transparencies are used in structural geology and photogeology classes to help to see the larger regional aspects of structure as well as providing excellent illustrations of folds and faults and uplifts and basins. The imagery has identified areas for detailed surface mapping by graduate students. The imagery is continually being examined by many students.

REFERENCES

Blackstone, D.L. Jr., 1940, Structure of the Pryor Mountains, Montana: Iowa Geology, v. 48, p. 590-618.

Hoppin, R.A., and T. V. Jennings, 1971, Cenozoic tectonic elements, Big Horn Mountain region, Wyoming-Montana: Wyoming Geol. Assoc. Guidebook, 23d Ann. Field Conf., p. 39-47.

Hoppin, R.A., R.D. Manley, D.M. Tappmeyer and N.E. Voldseth, 1973, Geologic interpretation of ERTS-1 imagery, Big Horn Mountains: Contributions to Geology, Univ. Wyoming, v.12, p. 33-42.

Hoppin, R.A., 1974, Lineaments: Their role in tectonics of Central Rocky Mountains: Am. Assoc. Petroleum Geologists Bull., v. 58, p. 2260-2273.

Swenson, A.L., 1973, Evaluation of ERTS-1 imagery on the Tensleep fault and southern Big Horn Basin, Wyoming: Contributions to Geology, Univ. of Wyoming, v. 12, pp. 99-104.

Tappmeyer, D.M., 1974, The application of orbital imagery in the interpretation of the geology of the Nowood area, Washakie County, southern Big Horn Basin, Wyoming: Unpubl. M.S. thesis, Univ. of Iowa, 65 p.