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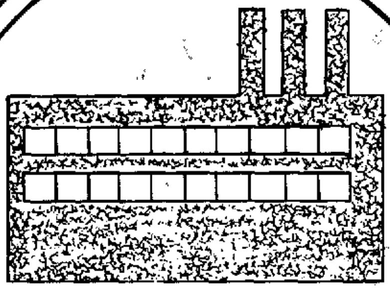

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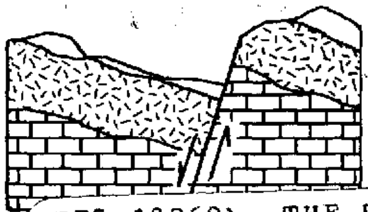

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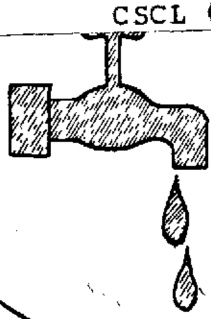

University of Wyoming

SPECIAL REPORT - THE USE OF SKYLAB AND ERTS IN A GEOHYDROLOGICAL STUDY OF THE PALEOZOIC SECTION, WEST-CENTRAL BIGHORN MOUNTAINS, WYOMING.

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Figure 2. Technical Report Standard Title Page

ABSTRACT

The Use of Skylab and ERTS in a Geohydrological Study of the Lower Paleozoic Section, West-Central Bighorn Mountains, Wyoming.

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Sites of geologic structures were identified using Skylab and ERTS imagery, and their relationships to groundwater recharge and discharge were studied. The study area lies along the western slope of the Bighorn Mountains. Runoff flowing from the Precambrian core of the Bighorn Mountains sinks as it flows over outcrops of the Bighorn dolomite. A comparison of photo-geologic maps prepared from Skylab and ERTS imagery and a geologic map compiled by Darton (1906) illustrates that photomapping, by itself, cannot supply adequate detail but can supplement reconnaissance mapping. Lineation maps were compiled from ERTS and Skylab images and compared to similar maps compiled by other investigators. Many of the lineations are expressions of tectonic activity that affect fractures, and consequently, groundwater recharge. Hydrologic features, in the form of sinks and springs, on four creeks in the study area were located on the lineation maps and their relationships to the lineations were observed. A direct correlation exists between mapped lineations and the hydrologic features. A comparison of the interpretations of other investigators, made independent of the geohydrological study, also show a direct correlation. This observation indicates direction of movement and the quantity of groundwater recharge and discharge, expressed as fracture concentration, may be estimated by comparing lineation maps to drainage and geologic maps in areas where groundwater movement is fracture controlled.

THE USE OF SKYLAB IN A GEOHYDROLOGICAL STUDY OF THE LOWER PALEOZOIC SECTION, WEST-CENTRAL BIGHORN MOUNTAINS, WYOMING

Introduction

Satellite imagery was used as an aid in the identification of sites of groundwater recharge and discharge to the Bighorn Basin of northern Wyoming. The study area lies along the western slope of the Bighorn Mountains between Shell Canyon and the Tensleep fault encompassing approximately 700 square miles (Figures 1, 2a, and 2b). In this region, the Paleozoic rocks that comprise the aquifer are impermeable unless fractured. Groundwater itself cannot be detected from satellite imagery but geologic structures controlling recharge are readily observed. ERTS imagery, and Skylab and high-altitude aerial photography have proven valuable in defining the structural framework of the region.

Paleozoic rocks cropping out in the study area include the Pennsylvanian Tensleep and Amsden formations, Mississippian Madison limestone, Ordovician Bighorn dolomite, and Cambrian Gros Ventre, Gallatin, and Flathead formations. Runoff flows from the Precambrian core of the Bighorn Mountains across the Paleozoic section and into the Bighorn Basin. Water normally carried in surface streams often sinks as it flows over the outcrops of the Bighorn dolomite, the first Paleozoic carbonate encountered in the downstream direction. Down-gradient, but up-section, a portion of the water lost to sinks reappears in springs. Known sinks and springs are located on Figures

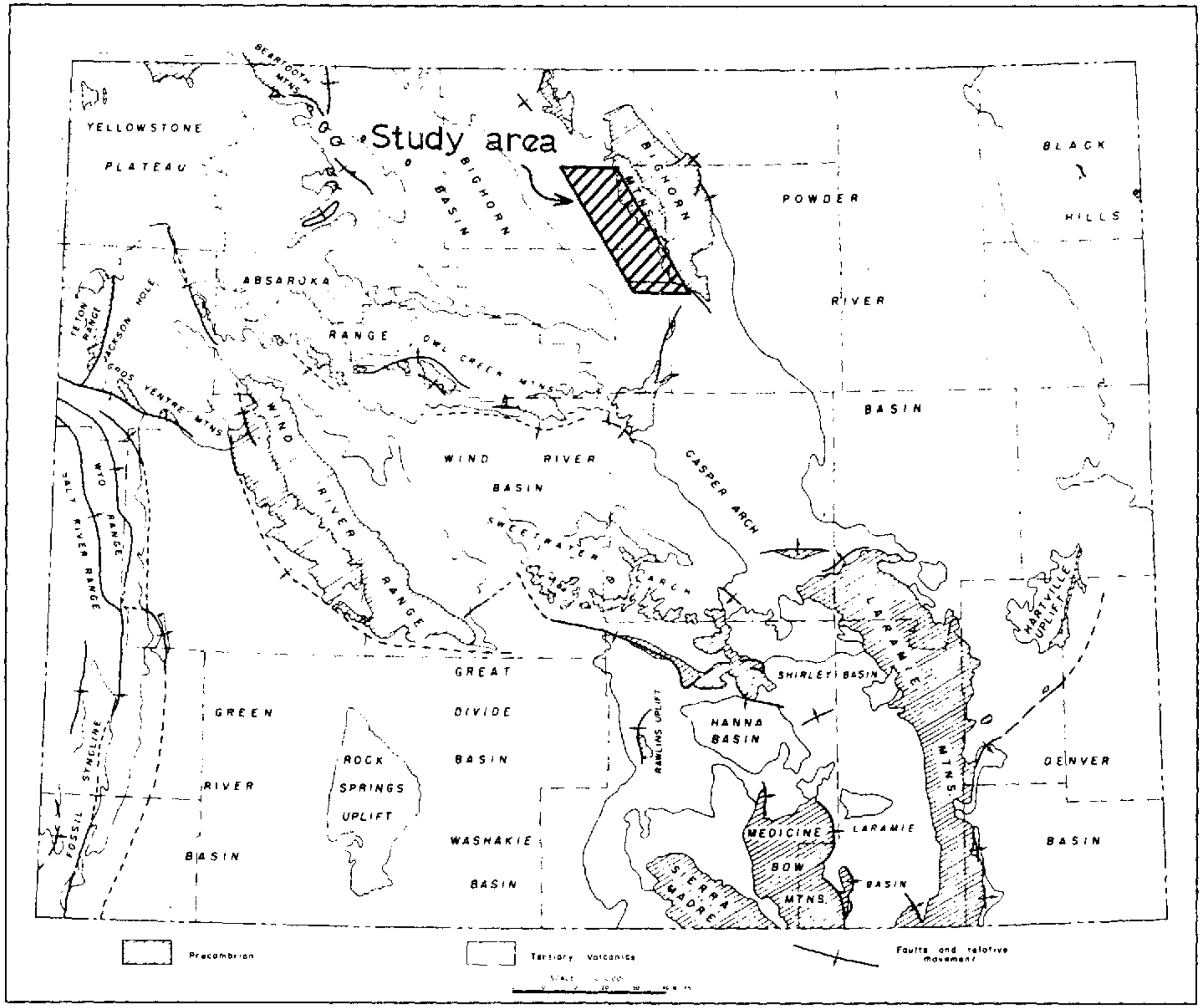


Figure 1. Index map of Wyoming showing study area.

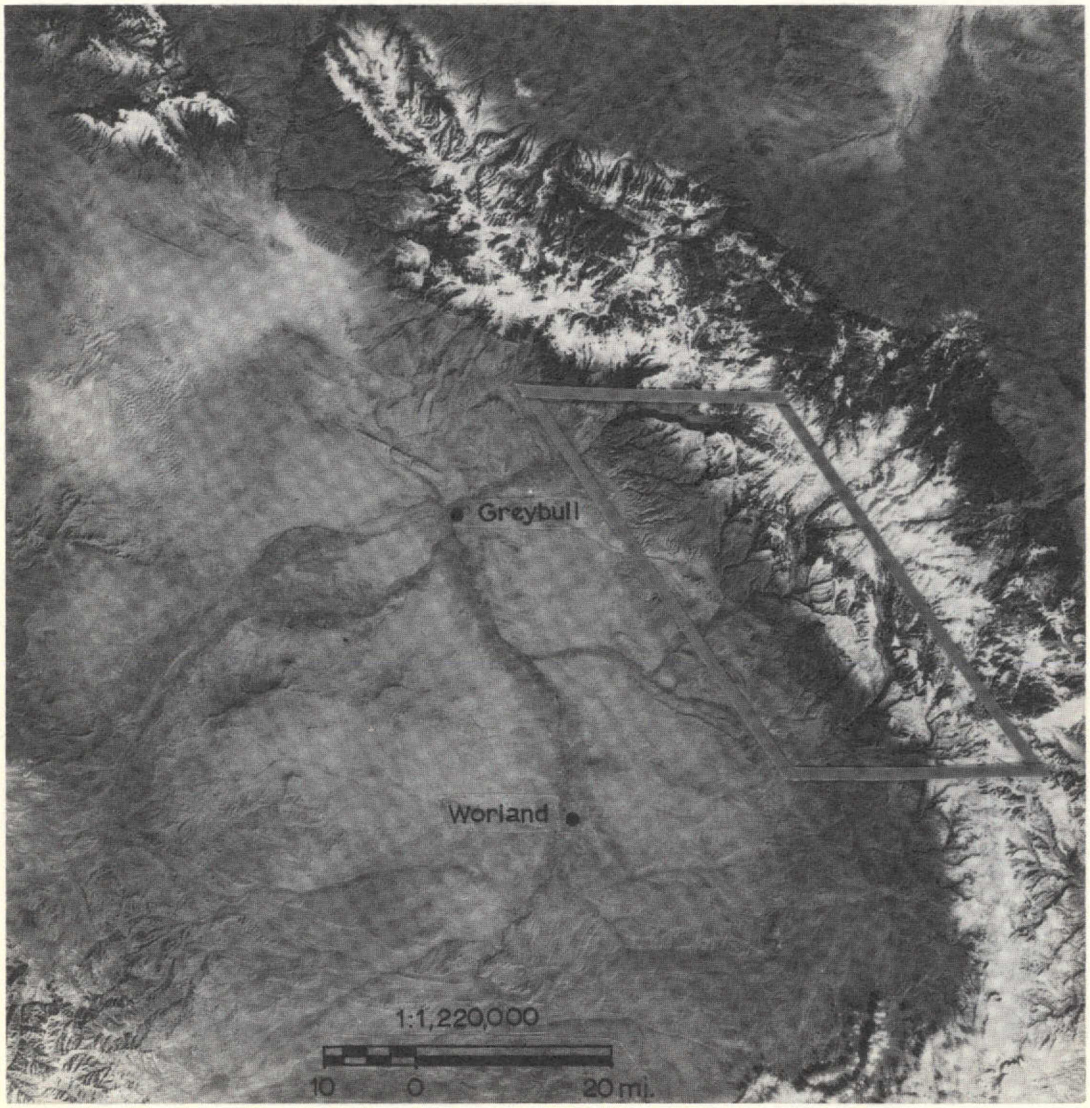


Figure 2a. Erts image 1121-17301-5, 21 November, 1972, showing Bighorn Basin and Bighorn Mountains. Study area is outlined.

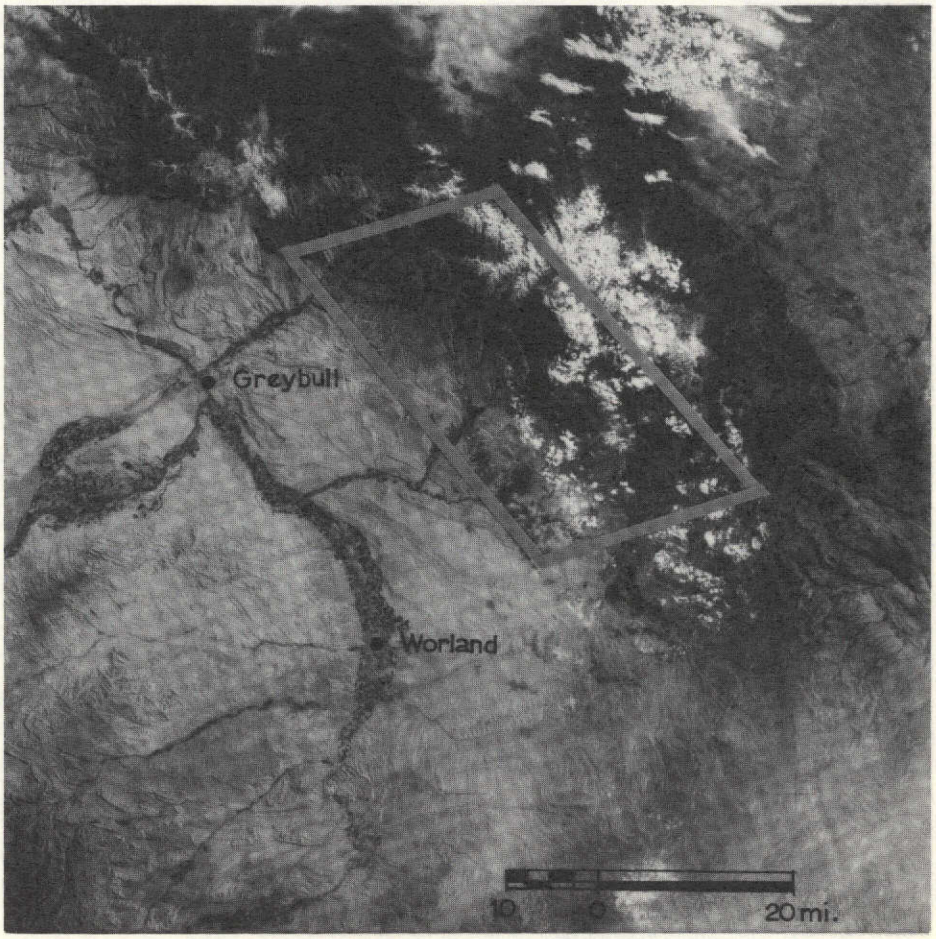


Figure 2b. Skylab II, track 5, pass 10 photograph, frame 228, June 13, 1973, showing Bighorn Basin and Bighorn Mountains. Study area is outlined.

3a and 3b. All the upstream sinks are found in the Bighorn dolomite. Springs downstream are usually found in the Madison limestone. In two cases the water sinks and rises twice in a single drainage.

On the four particular creeks in the study area, the upper sinks are associated with cavern systems ranging from a few hundred feet to almost one mile of known passage. The significance of the sinks, springs, and lineations may best be exemplified by P-bar Cave on Medicine Lodge Creek, which developed as Medicine Lodge Creek eroded into the Bighorn dolomite. The occurrence of slickensides of the walls of the cave demonstrates structural control of the passages. A large volume of water flows into the cavern and follows passages developed along fractures. One quarter mile downstream from the sinks, water rises in the bed of Medicine Lodge Creek from springs probably controlled by bedding planes, fractures, or both.

Previous Work

Darton (1906) compiled the only published geological map of the entire area. Wilson (1938) studied a one-to-five mile wide strip along the Tensleep fault, Lowry (1962) wrote a USGS open file report on groundwater in the vicinity of the town of Tensleep, Wyoming, Mackin (1947) and Fanshawe (1971) described the structural evolution of the Bighorn Basin, and Hoppin and Palmquist (1965) and Hoppin, Palmquist, and Williams (1965) defined tectonic controls in the Bighorn Mountains. Blackstone (1973), Hoppin (1973), and Hoppin and Jennings,

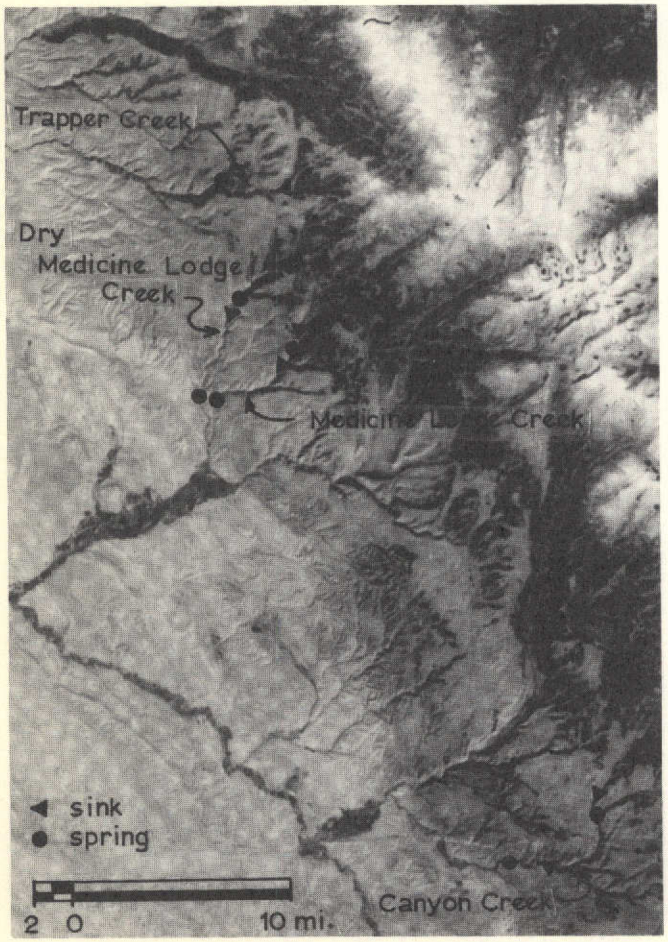


Figure 3a.

Figure 3b.

Skylab II Track 5 pass 10 S190-B photograph and ERTS-1 image 1409-17285-5 showing location of known sinks and springs on four creeks in the study area.

(1971) have studied the structural geology in north-central Bighorn Mountains and used satellite imagery in their work.

Methodology

Several types of imagery are available for this area; ERTS (1:3,000,000), Skylab S-190A (1:2,800,000), Skylab S190B (1:850,000), and aircraft (various scales). Although the study involved all three types of imagery, only applications of ERTS and Skylab imagery will be summarized here. Prior to interpreting the imagery, the writer spent several weeks mapping the geologic and hydrologic features in parts of the study area during the summer and fall of 1974. As a result, many of the interpretations reflect experience gained from the field studies.

The ERTS and Skylab images examined are described in Table 1.

ERTS

Date	Image Number	Ground Condition	Image Quality
5 Aug 72	1013-17291	no snow cover	excellent
5 Sep 73	1409-17285	10% snow cover	excellent
16 Oct 72	1085-17294	no snow cover	excellent
21 Nov 72	1121-17301	40% snow cover	excellent
1 Feb 73	1193-17301	90% snow cover	excellent
14 Feb 74	1571-17252	60% snow cover	excellent
19 Feb 73	1211-17302	total snow cover	excellent

Skylab

Date	Track Number	Pass Number	Image Number	Image Quality
13 Jun 73	5	10	S-190A Frames 227-229	10% cloud cover
			S-190B Frames 146-147	10% cloud cover

Table 1.

All available ERTS imagery for spring and early summer of 1972 and 1973 were cloud covered. The June 1974 images were cloud-free but were not available for this study.

Photogeological maps of the area were compiled first using ERTS (Figure 4a) and Skylab (Figure 4b). A comparison of the remote sensing maps and the geological map prepared by Darton (1906, Figure 5a) illustrates a similarity but the imagery revealed that Darton's map is geographically imperfect. For example, streams were misplaced and the aerial extent of outcrops was distorted. A Skylab image superimposed on Darton's map is used to refine the geologic mapping (Figure 5b). Streams were correctly placed and the geology was adjusted. Much detail, however, was not discernible. One problem encountered was the two completely different grid locations.

Lineation maps of the study area have been prepared by Blackstone (1973, Figure 6a), Hoppin (1973), Hoppin and Jennings (1971, Figure 6b), and Earle (unpublished, Figure 6c). Each map is somewhat different and reflect different interpretations. Two photolinear maps were compiled by the author for this report using ERTS (Figure 7a) and Skylab (Figure 7b). For the purpose of this compilation a lineation is defined as any feature (large or small) that appears to have lateral continuity. Such features include aligned stream channels and structural lineaments. Care was taken to eliminate cultural-related lineations such as tree lines, clear cutting, and fence lines. Figure 7a is a representation of "major" lineations or very broad scale

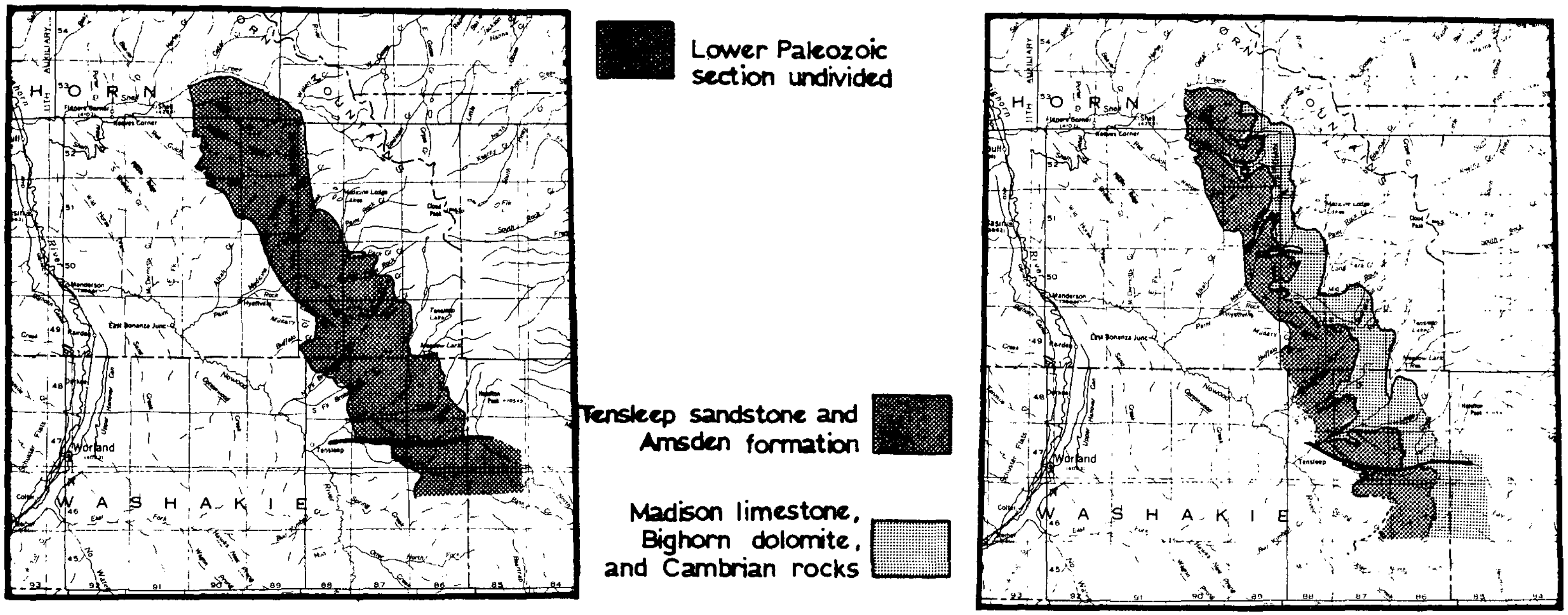
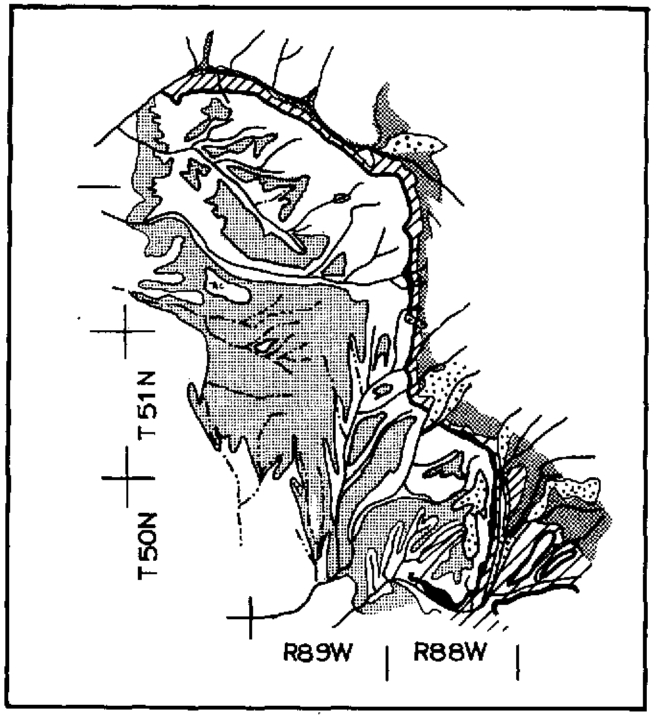
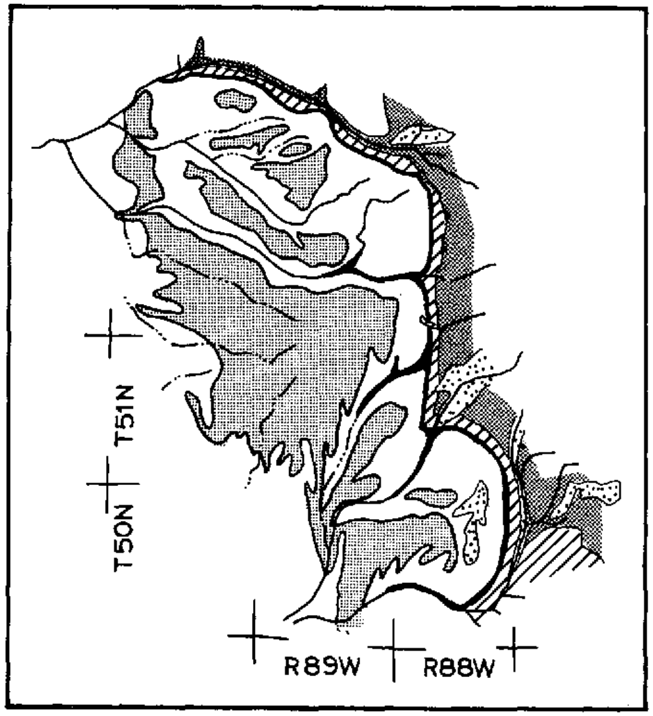


Figure 4a. Figure 4b.

Geology of study areas as interpreted from ERTS (a) and Skylab (b).



5a.

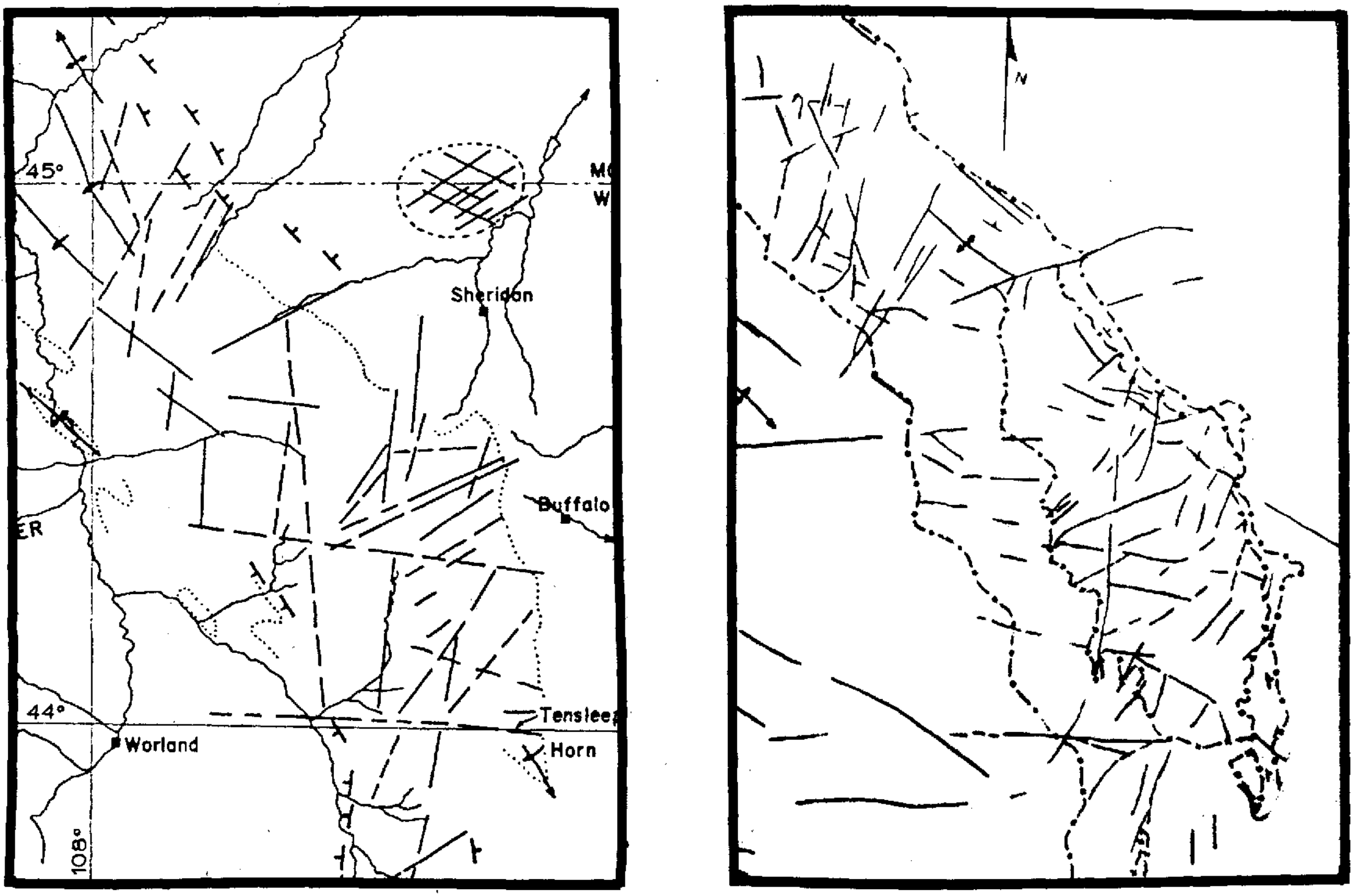


5b.

- Tertiary sediments
- Pennsylvanian Tensleep sandstone
- Mississippian Madison limestone
- Ordovician Bighorn dolomite
- Cambrian formations undivided
- Precambrian rocks

Figure 5a. Geological map compiled by Darton (1906).

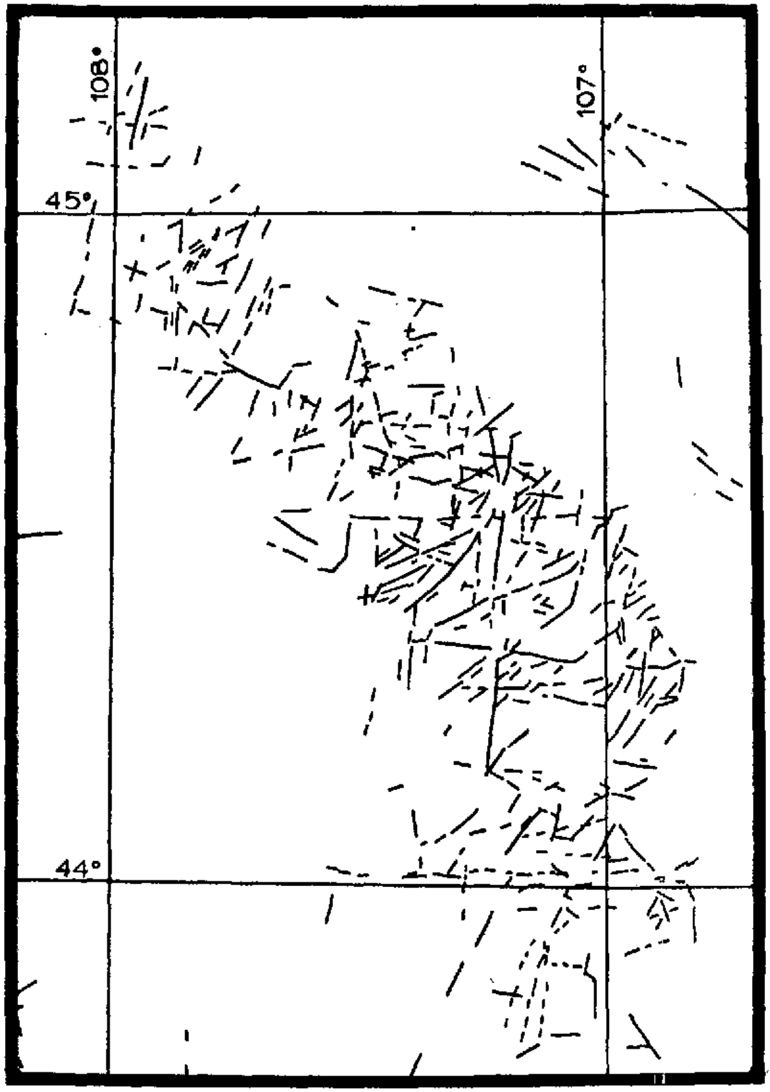
Figure 5b. Darton's geological map geographically corrected using Skylab photography.



(Blackstone, 1973)
6a.

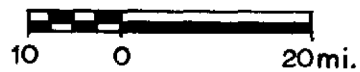
(Hoppin, 1973)
6b.

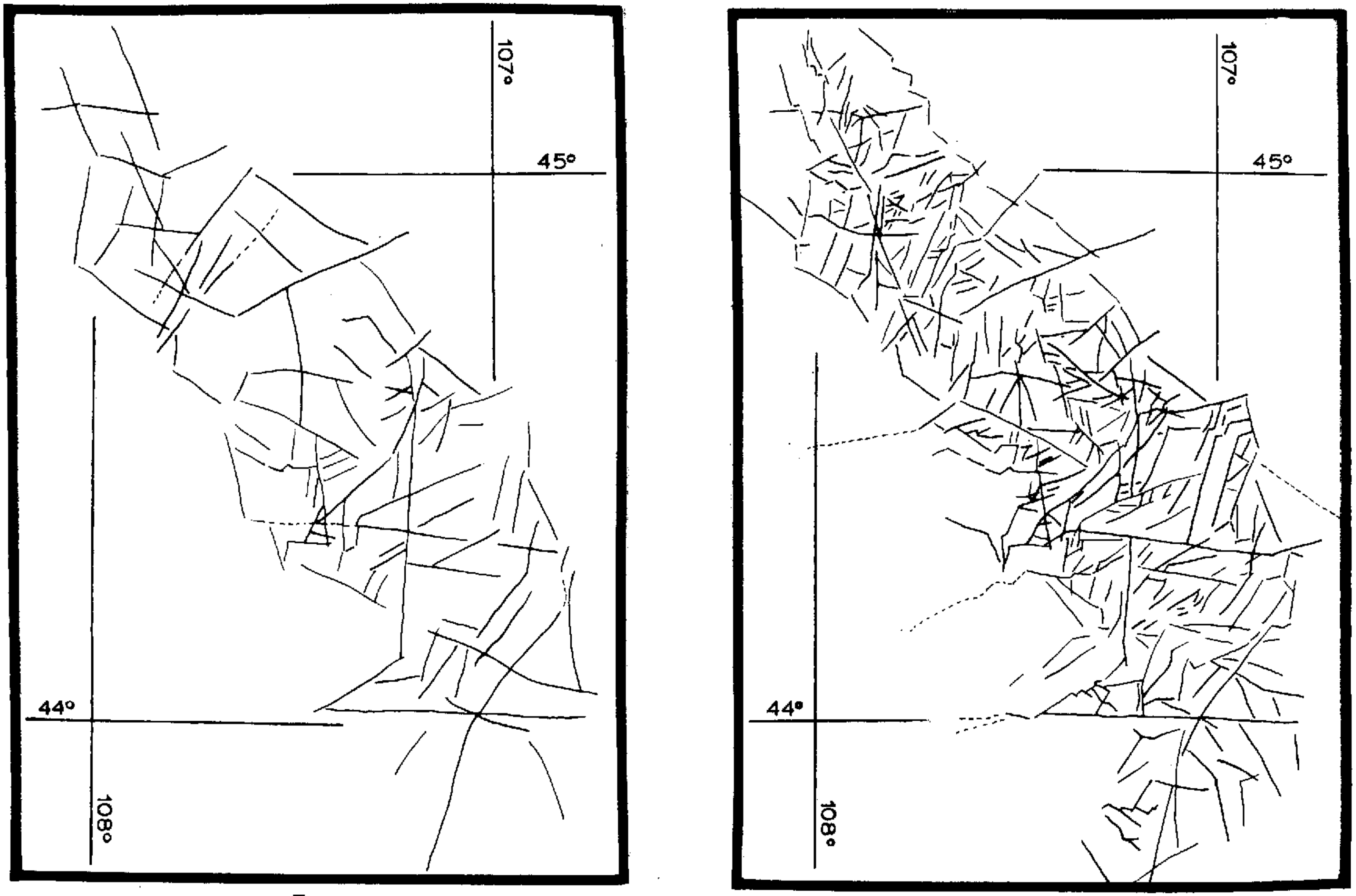
Photolineation maps of the Bighorn Mountains, compiled by Blackstone (1973) and Hoppin (1973).



Earle, (1974)
6c.

Figure 6c. Photolineation map of Bighorn Mountains compiled by Earle, (1974).





7a. Major Lineations

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7b. Minor Lineations

Figures 7a and 7b. Photolineation maps of the Bighorn Mountains.

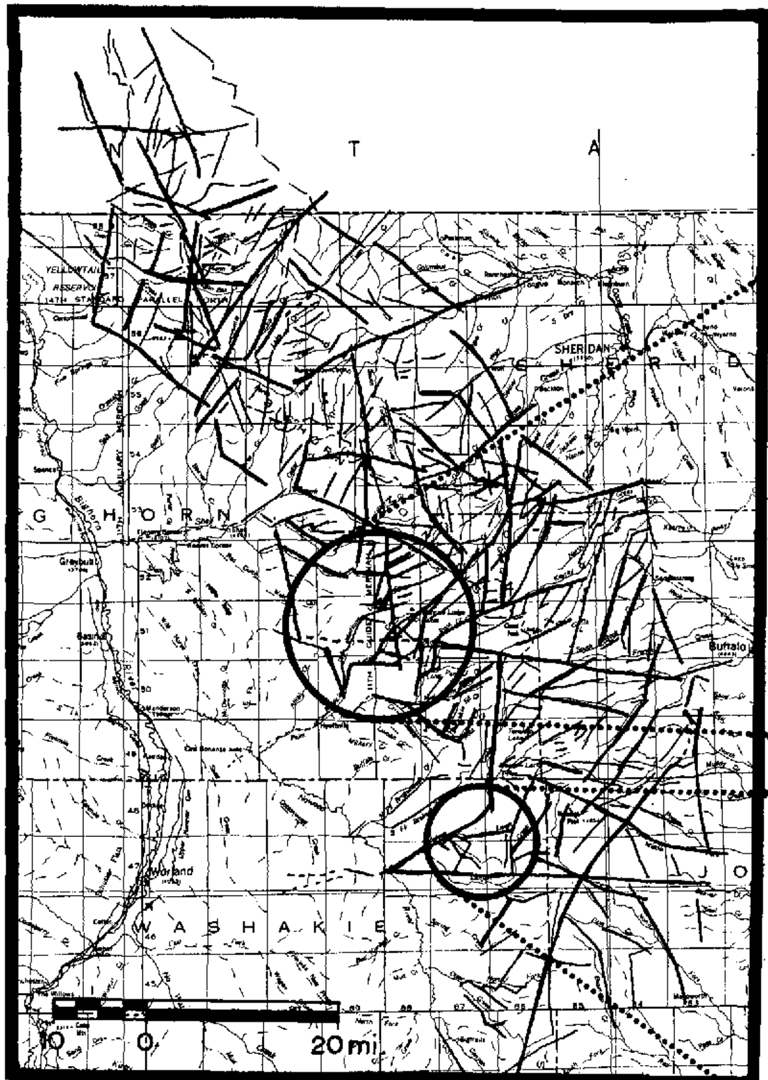
features easily detected at a glance. Figure 7b illustrates "minor" lineations or features which are much more subtle to detect, but reflect definite linear continuity. These maps were prepared from various interpretations compiled at different times from the different images described in Table 1.

Results

A direct correlation may exist between geohydrological features and lineations. Many of the lineations are expressions of tectonic features that affect the geohydrological system in the area. Lineations appear to correlate with fractures which control the flow of water. A comparison of the hydrological features and lineations (Figure 8a, 8b, and 8c) yields the following results in each of the four drainages in the study area:

Trapper Creek - The cave behind the sinks has not been explored due to a log jam but examination of springs downstream that rise from the Devonian rocks on the north face of Trapper Canyon suggests that the spring water is not the same water flowing into the sink. The sink occurs at the intersection of a major and minor lineation (Figure 8b). The minor east-west linear appears to line up with a line of mountain crests in the Precambrian core to the east. This alignment suggests that the minor lineation may be a major structural element. In that case, the sinks would occur at the intersection of two major lineations.

Dry Medicine Lodge Creek - One of the major cave systems known in the Bighorn Mountains occurs at the intersection of



8a.

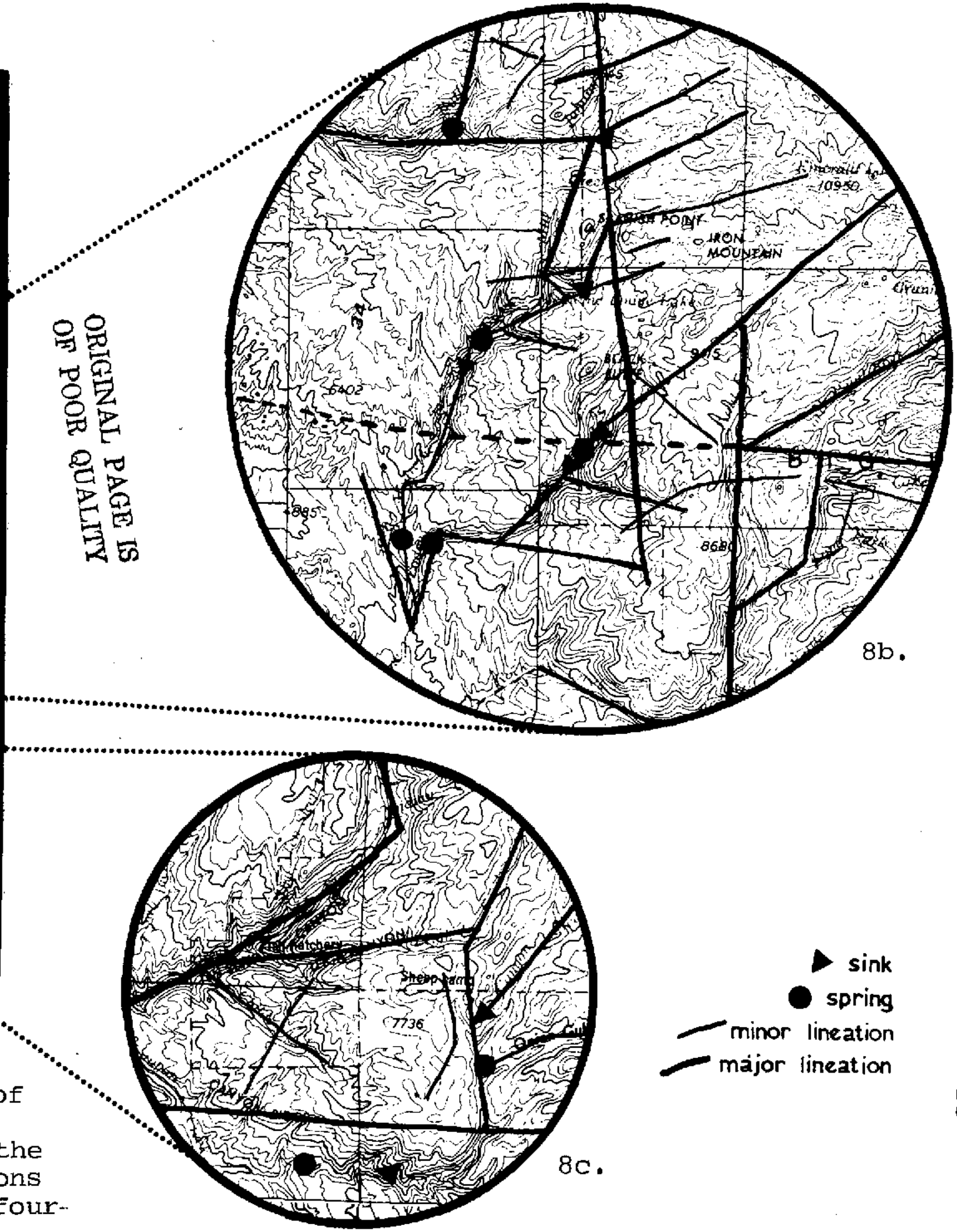


Figure 8a. Major and minor lineations of the Bighorn Mountains.
Figure 8b, 8c. Details (1:250,000) of the major and minor lineations in the vicinity of the four-creeks studied.

several lineations. Within the cave is a network of passages along joints, fractures and faults, many of which contain flowing water. The water does not reappear in any large sinks downstream and is assumed to be recharging the Paleozoic aquifer. A few miles downstream from the cavern, the position of the springs and sinks have migrated upstream during the summer and are presumed related to isolated water table conditions and not major linear elements. The springs furthest downstream issue from fractures in the Madison Limestone.

Medicine Lodge Creek - Located at the sinks of Medicine Lodge Creek is P-Bar Cave, a fracture controlled cave situated at the intersection of two major lineations. A large amount of water enters the cave and springs rise from the creek bed a few hundred feet below the cave. Dye-tests conducted by the author prove that this water is the same as that entering the cave. A number of minor lineations photomapped in the vicinity of the cave have an orientation parallel to the apparent orientation of passages within the cave.

Canyon Creek - The sinks and springs of Canyon Creek are each associated with major lineations. Dye tests conducted by the author revealed that the sinks and springs are directly connected and no groundwater recharge is occurring at this location. The upstream sinks and springs are both sites of open passable caves although open passage between the two does not exist. The downstream sinks and springs are not associated with caverns and they are clogged with debris.

Conclusions

The value of satellite imagery in the geohydrological application in this study results because the images aid the investigator in locating structural features that may influence groundwater flow. Results of this study suggest that the hydrologic features are partially controlled by large-scale structural features detectable on satellite imagery. A direct correlation exists between mapped lineations and the hydrologic features observed but because of the field research prior to the image interpretations, the author's interpretation may be biased. A comparison of the interpretations of other investigators, made independently of the geohydrological study, also shows a direct correlation between the location of sinks and springs with lineation or lineation intersections. This observation indicates direction of movement and the quantity of groundwater recharge may be expressed as a function of fracture concentration, taken from lineation maps that are compared with drainage and geological maps in an area where groundwater movement is fracture controlled. The right compilation of fractures, geology, and water drainage could result in a location of groundwater recharge and discharge sites. If one could assume similar relationships between structure and groundwater movement in other areas (such as on the east flank of the Bighorn Mountains) application of satellite data would be straightforward. Unfortunately, the hydrological systems in most areas are extremely complex and analyses require both remote sensing study and extensive field research.

The program of continuous ERTS coverage was particularly useful because it provided a capability to study imagery acquired during a number of weather and seasonal conditions. The disadvantage of ERTS imagery is its limited resolution. Definition of lithologic contacts is extremely difficult. The Skylab photography was far superior in resolution but cloud cover and shadows obscured part of the area. The discontinuity resulting from the cloud cover is a major disadvantage when using the photography in a reconnaissance study. The cloud-free portion of the Skylab photography is excellent for geologic mapping, particularly when utilizing the capability to view Skylab photography in stereo, but some units such as the Madison Limestone and Bighorn dolomite were difficult or impossible to differentiate.

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