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STRUCTURAL INTERPRETATIONS BASED ON ERTS-1 IMAGERY, BIGHORN REGION, WYOMING-MONTANA

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

ABSTRACT

Structural analysis is being carried out on bands MSS 5 and 7 of scene 1085-17294. Geologic structure is primarily revealed in the topographic relief and drainage. Topographic linears are particularly well developed in the Bighorn uplift. Many of these occur along known faults and shear zones in the Precambrian core; several have not been previously mapped. These linears, however, do not continue into the younger rocks of the flanks or do so in a much less marked manner than in the core. Linears are far less abundant in the basin or are manifested only in very subtle tonal contrasts and somewhat straight drainage segments. Some of the linears are aligned along trends previously postulated on the basis of surface mapping to be lineaments. The imagery reveals little or no evidence of strike-slip displacements along these lineaments.

Larger folds, such as the Sheep Mountain anticline, which are outlined by resistant units show up very well. Small folds or those outlined by nonresistant units or covered by Tertiary deposits are very difficult or impossible to discern.

The ERTS imagery provides especially fine detail in the uplifts. The imagery provides a basis on which targets for field checking and for supportive aircraft coverage can be efficiently chosen.

1. INTRODUCTION

This project covers an area (300 by 150 miles) extending from the eastern edge of the Black Hills to the western border of the Bighorn basin and from southern Montana to the south end of the Bighorn Basin. The principal objective is to determine the feasibility of utilizing ERTS imagery to delineate major lineaments.

Lineaments figure prominently in structural analyses and in theories regarding the tectonics of the North American Cordillera. Lineaments also are considered to be important features with regards to the occurrence of mineral deposits. Unfortunately facts relating to the existence and extent of lineaments are not always as hard or definitive as some writers seem to assume. Some lineaments are well established, but others are only provisionally located or are purely speculative. Much more work is needed to determine precisely the presence or absence of these large features and to define their characteristics.

Part of the problem of lineaments (and linears) lies in definition. Much of this appears to be due to a confusion between description and interpretation. The definition suggested here is purely descriptive. Lineaments are defined as generally rectilinear lines or zones of structural discordance of regional (100 miles or longer in length) extent. Lineaments are manifested at the surface in many diverse ways, as by single large faults or groups of faults subparallel to the lineament trend, by en-echelon oblique fault and fold belts, by large monoclines, and by juxtaposition of blocks of contrasting structures and lithologies. Other lineaments are suggested by lines of igneous bodies or alignments of ore deposits. Finally, others are revealed only by contrasting gravity and magnetic patterns related to subsurface rocks.

Linears are defined as individual straight lines a few miles or tens of miles in extent. Linears are commonly expressed in the topography and most often are structural features, but are not necessarily so. Linears can include single fault and fold-axial traces, steeply dipping dikes, hogbacks, straight drainage segments, and so on.

This paper will be restricted to a discussion of the study of a single MSS scene (1085-17294) which includes most of the Bighorn Mountains and a large portion of the Bighorn basin. Only structure will be covered here. Glacial, geomorphic, and vegetational aspects are being concurrently studied by the two co-investigators.

2. METHOD OF ANALYSIS

Geologic structure in this region is primarily revealed by topographic relief and drainage patterns. Topography in the uplift is especially emphasized in band 7 (Fig. 1) and stands out well both in mono-viewing and in stereo-viewing of side-lapping scenes.

Enlarged negative prints (Fig. 2) made from positive transparencies serve particularly well as bases for overlays. Detail can be enhanced by an optimum choice of exposure time and paper. We generally use two different exposure times in order to bring out the detail in uplifts and, separately, in the basins. Analysis of band 7 is supplemented with similar prints of band 5 in which vegetational contrasts are more apparent. False color infrared photographs have been made from an I^{2}s Addcol Viewer. These have not added significantly to structural interpretation, but will provide additional input into lithologic and vegetational analysis.

Linears and fold axes are plotted on the overlay of Figure 2. Criteria used to draw linears include topographic relief, drainage, and tonal differences. Note how the linears are much more apparent and concentrated in the uplift as compared to the basin. Also shown are the recognizable folds, the outline of the uplift (dot-dash line), and the Precambrian-Paleozoic contact (dash-cross line). Figure 3 is a map showing the known structures.

One of the reasons for having chosen this area was the considerable ground truth availa[illegible] However, when making an overlay, the P.I. found it difficult to b[illegible]ive and ignore his knowledge of the geology. To reduce the [illegible] bias, several others with little or no prior background in t[illegible]ere asked to do overlays. Comparisons showed a high degree of [illegible]nt. The main differences were in the individual's criteria for [illegible]aightness and minimum length of linears. The resulting overlay is believed to be a fairly honest and objective first look.

U-2 photography was flown along two east-west strips; one is at the latitude of Greybull and the other at the latitude of Tensleep. In addition conventional high altitude photography has been obtained for key areas chosen on the basis of the study of the ERTS imagery.

3. DISCUSSION

The linear pattern is made up of several distinct trends; E-W, NNE-SSW, NE-SW, and NN-SE. These directions correlate well with known faults, shear zones, and monoclines in the uplift. Several "on-line" linears coincide with previously known or postulated lineaments; these are the Tensleep, Florence Pass (west of Buffalo) and Tongue River (north and west of Sheridan). These features, however, either do not continue into the younger rocks of the flanks or do so in a much less marked manner than in the core.

Two prominent linears in the core of the uplift have not been previously mapped. One trends N-S from the glaciated West Tensleep valley north across the core to a pronounced kink in the northeast flank of the range. this is to be field checked. The other, a strong NE trend correlates with a newly mapped fault in the Precambrian (in a just published USGS Bulletin on The Cloud Peak Primitive Area).

On the other hand, the Tensleep lineament is not resolvable at its east end. Though not decipherable on the ERTS imagery because of the gravel and grass cover, it can be seen on U-2 and high altitude photography. It is also well known in the subsurface in the Bighorn basin, although its delineation at the surface is poor or nil. A possible surface discordance at the west side of the basin will be investigated in the summer. The postulated lineament in Fig. 3 does not appear to be confirmed in the imagery; rather, the fault at the north end of the thrust is probably only a local tear fault associated with the overthrusting. The Tongue River lineament, long a source of controversy regarding its existence, stands out strongly.

Linears are much less evident in the basins. The folds shown in the southwest corner of the overlay are recognizable owing to the resistant hogbacks of Cretaceous Mesa Verde sandstones. The two folds to the north are marked by resistant upper Paleozoic carbonates and sandstones. Other folds cannot be deciphered either because no resistant units are exposed or they are covered by Tertiary sediments.

The prominent linears mostly occur along very old structures which have been partially reactivated during the Cenozoic. Lack of expression in the basins suggests one or a combination of the following:

1) the thick cover above the basement has masked or absorbed the later movements.

2) the later movements have been concentrated in the uplift.

Tonal contrasts in the Bighorn basin are mainly lithologic as the soil and vegetation cover is very thin. The lack of tonality contrast and the more dense drainage pattern in the Powder River Basin is related to the moister climate with a resultant heavier grass cover, and to the more widespread and thicker post-Paleocene cover.

To date, vegetation contrasts have not been too helpful in providing ructural information. Conifer-bearing Cretaceous sandstones do outline a few hogbacks, as around the Black Hills. Within the Precambrian core portions of dikes greater than 150 feet wide are marked by vegetational contrast from the surrounding gneisses.

An RBV scene of the same region (1013-17291) does not show as much detail as the MSS scene. An enlarged, enhanced negative print of band 2 nevertheless provides a synoptic view that can still be of use alone.

Fig. 1 - Positive print, MSS-7

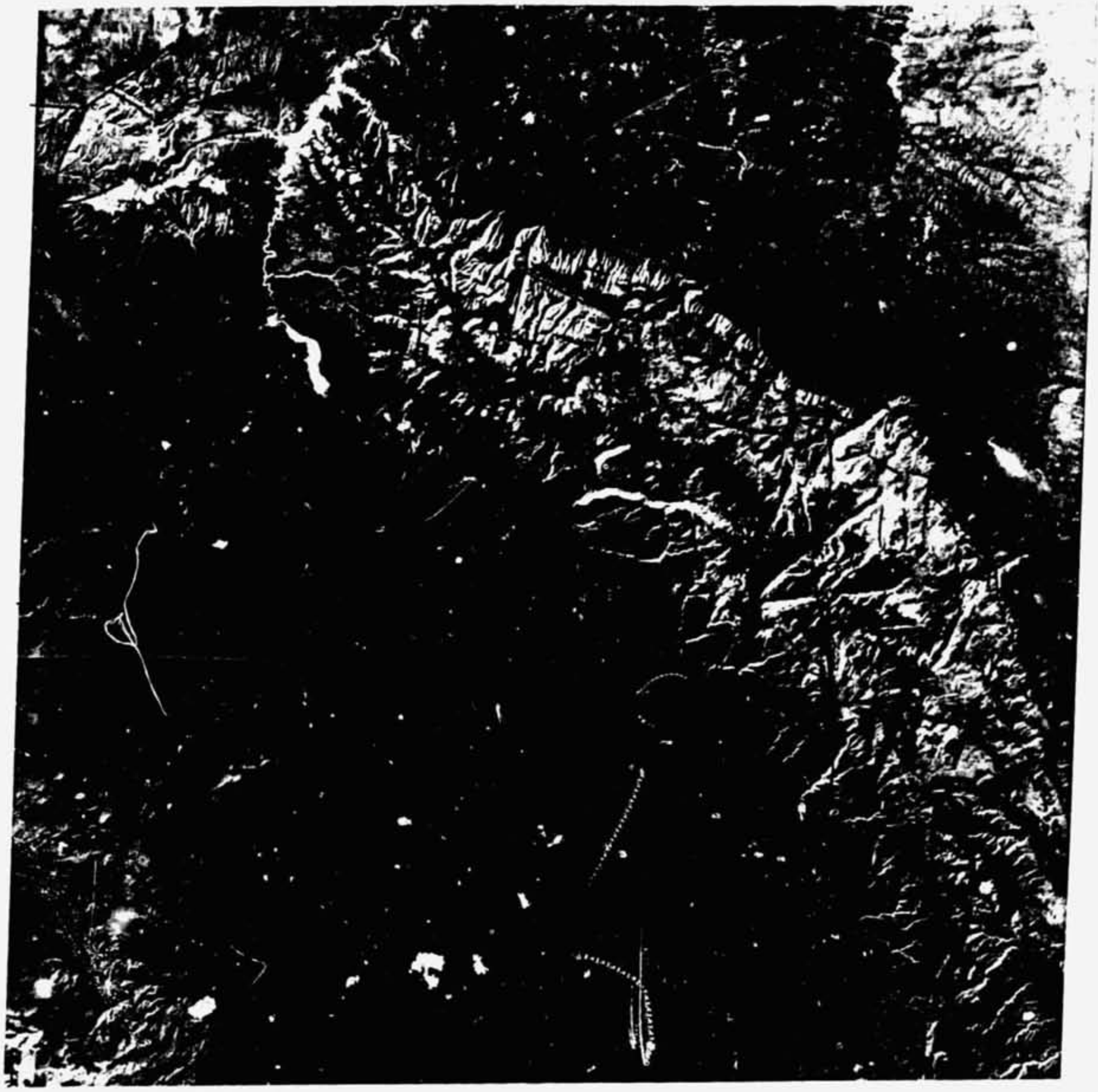

Fig. 2 - Negative print, MSS-7 with overlay. See text for annotation.

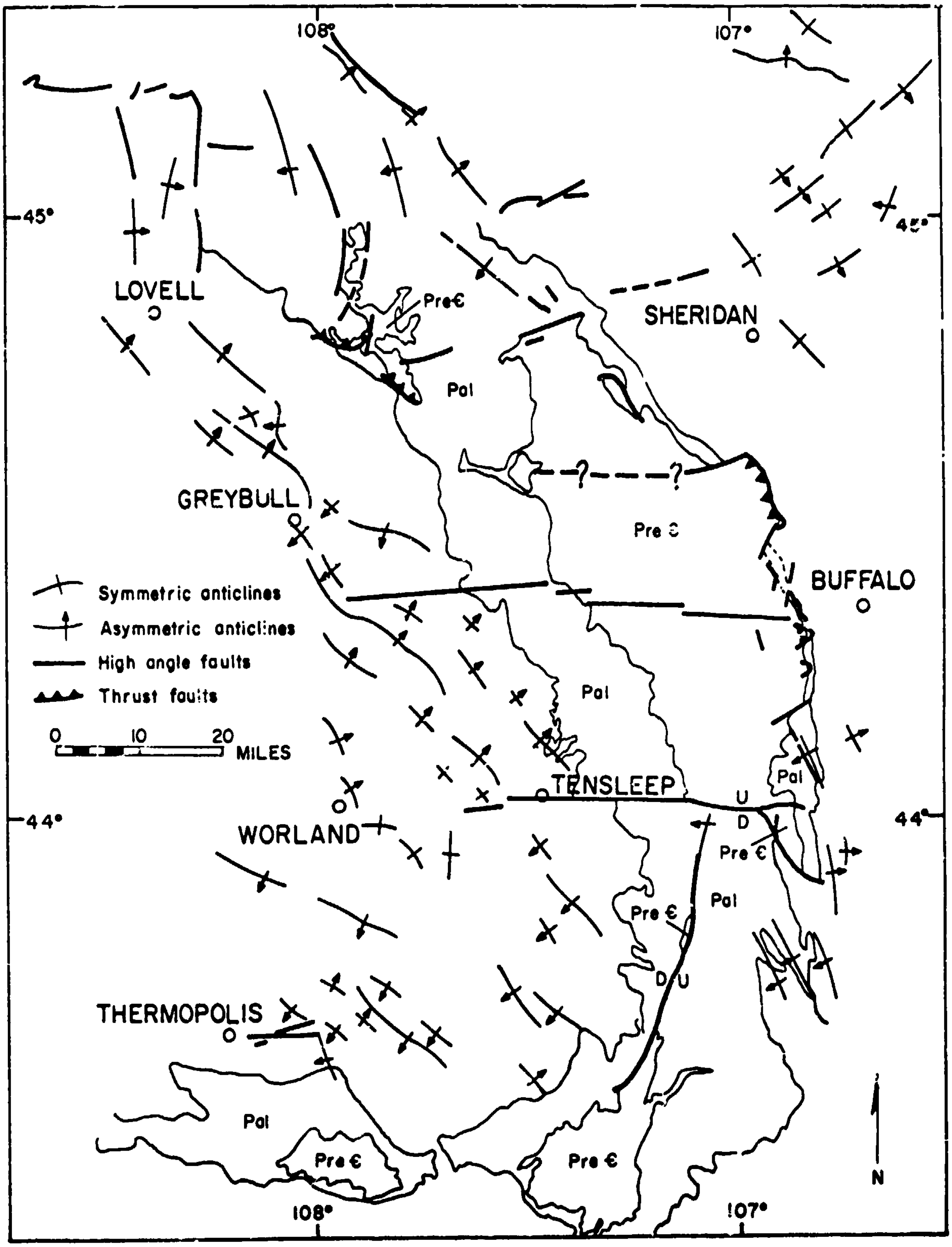

Fig. 3 - Map showing known structures

4. SUMMARY AND CONCLUSIONS

The ERTS MSS imagery, particularly band 7, provides an unparalleled structural overview unobtainable by any other means. Considerable detail is shown in the mountain uplifts and in those portions of the adjoining basins where the post-Paleocene rocks have been removed. Even though structures in the basins may be covered, extrapolation from the marginal features shown on the imagery would be warranted. In other words, in regions where far less is known of the geology as is the case here, one might predict the subsurface occurrence or folds and lineaments and hence more confidently explore the covered areas for concealed oil structures and mineral deposits.

For example, mineralization occurs along the Tensleep fault. The fault is only partly traceable on the imagery, but is known to be more extensive. The imagery allows one to more efficiently plan supporting flights (as the U-2 in this case), to select pertinent photography from available mosaics, and to plan the ground field work. Without the imagery to provide clues and to narrow the target, we would literally be feeling our way trying to verify the presence or absence of lineaments in the basins.

Finally, analysis of the imagery reveals little or no evidence of strike-slip displacement along the lineaments, a basic assumption upon which is founded a group of hypotheses invoking large scale horizontal movements along lineaments in the Cordillera.