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APPLICABILITY OF ERTS-1 TO LINEAMENT AND PHOTOGEOLOGIC MAPPING IN MONTANA -- PRELIMINARY REPORT

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ABSTRACT

A lineament map prepared from a mosaic of western Montana shows about 85 lines not represented on the state geologic map, including elements of a northeast-trending set through central western Montana which merit ground truth checking and consideration in regional structural analysis. Experimental fold annotation resulted in a significant local correction to the state geologic map. Photogeologic mapping studies produced only limited success in identification of rock types, but they did result in the precise delineation of a late Cretaceous or early Tertiary volcanic field (Adel Mountain field) and the mapping of a connection between two granitic bodies shown on the state map. Imagery was used successfully to map clay pans associated with bentonite beds in gently dipping Bearpaw Shale. It is already apparent that ERTS imagery should be used to facilitate preparation of a much needed statewide tectonic map and that satellite imagery mapping, aided by ground calibration, provides an economical means to discover and correct errors in the state geologic map.

TECTONIC MAPPING STUDIES

A lineament map for western Montana (Fig. 1) was drawn as an overlay to a Band 7 mosaic laid directly from 9-inch prints supplied by the NASA Data Processing Facility. Most of the mapped lineaments appear to be topographic expressions of fracture (scarps and straight canyons); a few are inclined, resistant strata. They range in length from 8 to 130 km. Lineaments were checked against the geologic map of Montana (1:500,000 scale, Ross and others, 1955) and against newly-compiled test site geologic maps representing approximately one quarter of the total area covered. More than 50 of them appear to be hitherto unrecognized possible faults which will be investigated. Among some 130 lineaments annotated, lines of northeast trend are much more common than was anticipated and those of northwest trend much less so. Shadow enhancement aids significantly in recognition of lineaments trending in all directions except northwest-southeast.

Most of the important normal faults in the area are represented on the lineament map. In the area east and north of Flathead Lake these tend to appear as scarps. In southwestern Montana they mark the boundaries between mountain blocks and Tertiary intermontane basins. Faults bounding the northeastern and northwestern sides of the Ruby Range, the west side of the Tobacco Root Mountains, and the western flanks of the Madison, Gallatin and Bridger Ranges are especially good examples. Lineaments mapped in southwestern Montana from ERTS imagery compare well with faults mapped by Burfeind (1967) with the aid of extensive geophysical work.

Low angle faults, such as the Lewis overthrust, are not readily apparent. Higher angle reverse-slip faults might be inferred from the arcuate pattern of parallel ridges in the Sawtooth Range structural salient about 75 miles west of Great Falls.

Short and medium length lineaments of northeast trend are prominent in a broad zone southeast of a line connecting Missoula and Great Falls; they appear to represent a significant fracture trend not hitherto appreciated. One such lineament defines the straight, southeast-dipping flank of the Little Belt uplift. Another, followed by the valley of the Little Boulder River, trends toward the strongly mineralized mining district at Butte.

Northwest trending faults are difficult to see because of their orientation parallel to the illumination direction. An exception is the Shroder Creek fault, clearly visible on ERTS imagery as a lineament extending 17 miles west from Flathead Lake, but mapped with considerable difficulty by LaPoint (1971), who showed that it has undergone one to two miles of right slip.

Of six prominently visible west-trending lineaments crossing the Kootenai River Canyon in extreme northwestern Montana, none are shown as faults on the state geologic map and only the southernmost two on the 1:125,000 scale geologic map (Johns, 1970). Two minor shocks recorded by the Libby Dam seismic network in August, 1972 have been referred to epicenters along these lineaments (personal communication, Gary H. Crosby, University of Montana).

Rather detailed mapping of folds in differentially eroded Paleozoic and Mesozoic strata is possible for areas of moderate relief and scanty forest cover. Study of the area between the Elkhorn and Crazy Mountains indicates that the low sun angle imagery of November (1106-17465-7) is much better for such mapping than that taken in August. Ridge patterns often allow delineation of plunging folds with wave lengths of a few kilometers; resolution of axial traces 1.6 km. apart is possible. Land form indication of dip direction allows identification of fold type at scattered locations. The most successful fold mapping utilized 1:500,000 scale enlargements under overlays and at 2x magnification under the zoom transfer scope. Annotation of a plunging fold pair suggests a significant correction to the state geologic map for nose pattern and trend, involving a shift of an axial trace by as much as 2.6 km.

PHOTOGEOLOGIC MAPPING STUDIES

Efforts to develop criteria for photolithologic recognition of rock types and rock units from ERTS imagery have met with limited success. It is possible, with some assistance from ground truth information, to delineate the boundaries of certain major rock bodies, including those of Cenozoic basin fill, upturned Paleozoic and Mesozoic strata, and the igneous rock bodies discussed below.

Large volcanic piles are distinctive in ERTS imagery because of their tonal quality, their lack of strongly apparent internal geologic structure or structurally controlled drainage patterns, and their tendency to bury structures evident in adjacent older rocks. The Adel Mountain volcanics, of latest Cretaceous or earliest Tertiary age, were successfully delineated with only minor departures from the outlines shown on published maps, as were satellite laccoliths to the north (Fig. 2). Four topographically expressed dikes in a swarm extending northward from the main body of volcanics were recognized even though their thicknesses are well below resolution limits. Other large volcanic piles in western Montana, such as the Elkhorn Mountains and Lowland Creek fields, are less apparent, but the latter was mapped with considerable success. Outlying areas of structurally deformed Elkhorn Mountains volcanics were not recognized in imagery.

Large granitic batholiths, such as the Boulder batholith, are moderately distinctive in ERTS imagery because of their intermediate tonal quality, lack of apparent internal geologic structure, and strong tendency for control of drainage patterns by fracture sets. Smaller granitic intrusions are more readily apparent through their structural effect on the country rock than through any distinctive quality in the appearance of the intrusive rock itself. Efforts to delineate the outlines of batholithic intrusions of granite in the Pioneer Mountains led to a map (Fig.3) showing both strong correlations and major departures from the outlines shown on the state geologic map. Both the correlations and the departures are believed to be significant and this area will be examined during the coming field season.

Small granitic stocks and laccolithic intrusions of alkaline rocks are numerous in several parts of the area covered by our imagery. These tend to draw attention to themselves through their darker tonal quality, a matter of vegetative cover rather than of rock tone, but other criteria make them distinctive. Laccoliths normally exhibit circular outlines and domal form, whether or not their igneous cores are exposed. Upturned edges of sedimentary beds along the flanks of both laccoliths and granitic stocks are clearly evident in ERTS imagery.

BEARPAW SHALE BENTONITE STUDY

The possibility of recognizing Bearpaw Shale known to contain bentonite beds of economic potential was investigated for an area on the flanks of the Ingomar anticline where ground truth is well known (Berg, 1970). The area is about 130 km northeast of Billings. Using a 1/500,000 scale negative print, an overlay map (Fig.4) was drawn to show highly reflective areas of irregular pattern as well as a continuous tonal boundary thought to represent a lithologic contact. The results were compared to a ground truth map and large scale aerial photographs covering most of the bentonite deposits in the area.

Known bentonite exposures in the area are too small to be recognized directly in the ERTS imagery, but the irregular reflective patches may be a clue to their occurrence. These areas of high reflectivity are surficial clay pans, mud-filled channels and depressions, that develop on the Bearpaw Shale where dips are less than 3 degrees and bentonite beds well exposed. Further work may show that areas of high reflectivity can be used for recognition of those areas within the Bearpaw Shale where bentonite beds are exposed.

CONCLUSIONS

ERTS imagery is potentially a major tool for improving geologic knowledge of Montana. Lineament mapping has already successfully identified previously unmapped faults and emphasized the importance of northeast-trending fractures. Experimental annotation of folds has demonstrated that imagery may be used to correct errors in trend and location of axial traces inferred from the state geologic map. Satellite imagery should be used to expedite preparation of a much needed tectonic map of the entire state at a scale as large as 1:500,000. Use of imagery for tectonic mapping should result in significant saving in time and money, as well as identification of previously unmapped faults. A probable bonus would be the extension of known faults and the recognition of patterns for shorter lineaments important to regional structural analysis.

Photolithologic recognition of at least some major rock units is possible with the help of limited ground truth information. Delineation of their boundaries as expressed in ERTS imagery should lead to significant refinement of the state geologic map.

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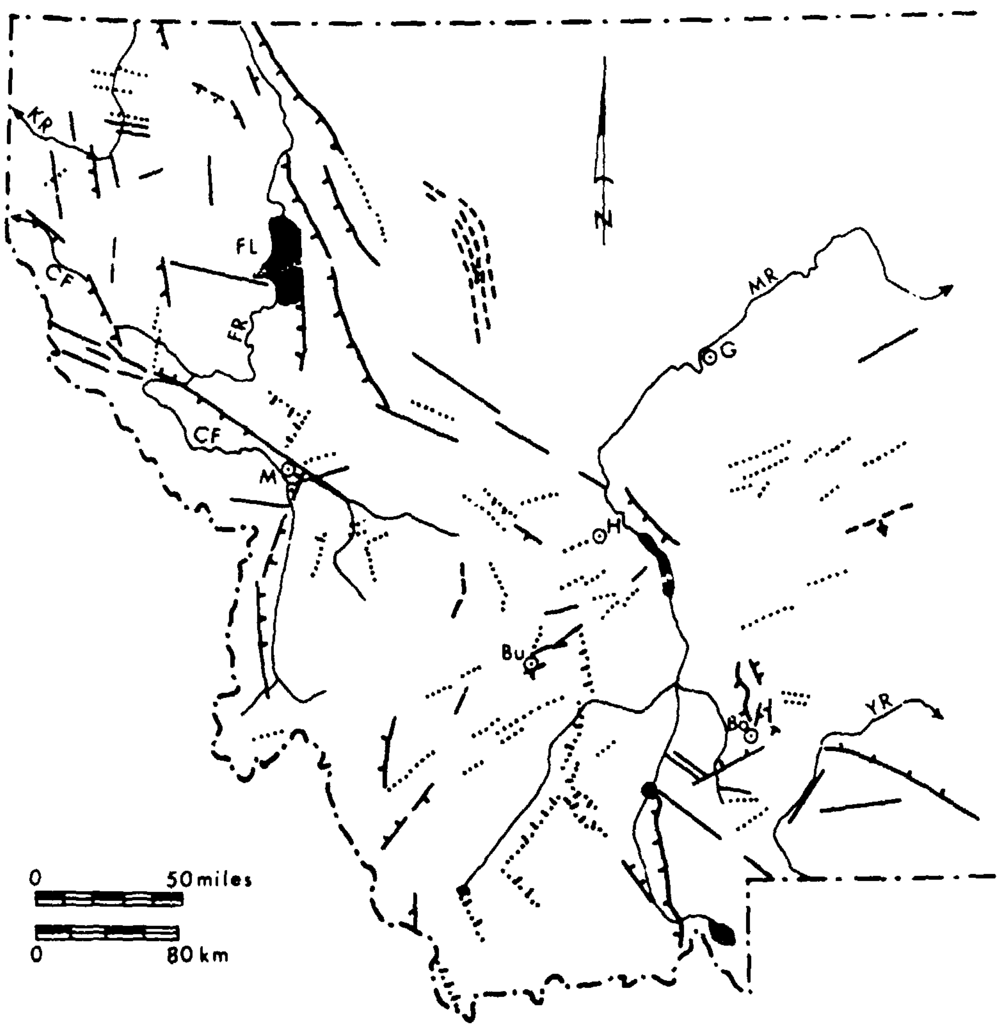


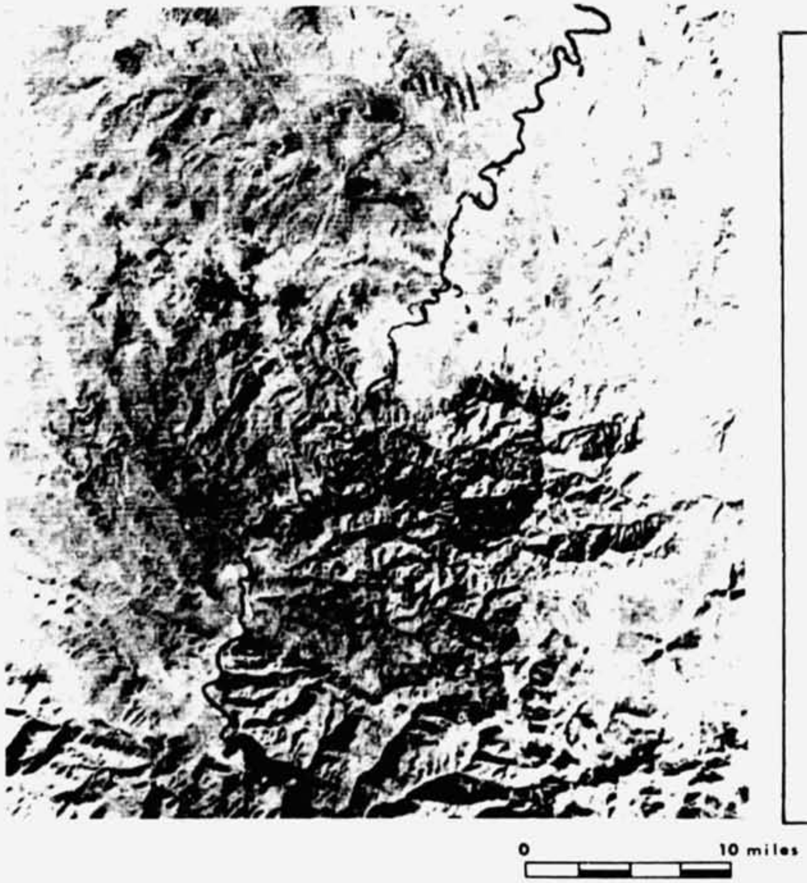
Hachured lines represent scarps. Plain lines show straight canyons.

known fault specifically recognized as imagery lineament

lineament not represented on state or test site geologic maps

---- inclined, resistant strata

Fig. 1. Preliminary ERTS-1 lineament map of western Montana, drawn originally at 1:1,000,000 scale on overlay of Band 7 mosaic for late August, 1972. M - Missoula, Bu - Butte, Bo - Bozeman, H - Helena, G - Great Falls, KR - Kootenai River, CF - Clark Fork of Columbia, FR - Flathead River, FL - Flathead Lake, MR - Missouri River, YR - Yellowstone River.



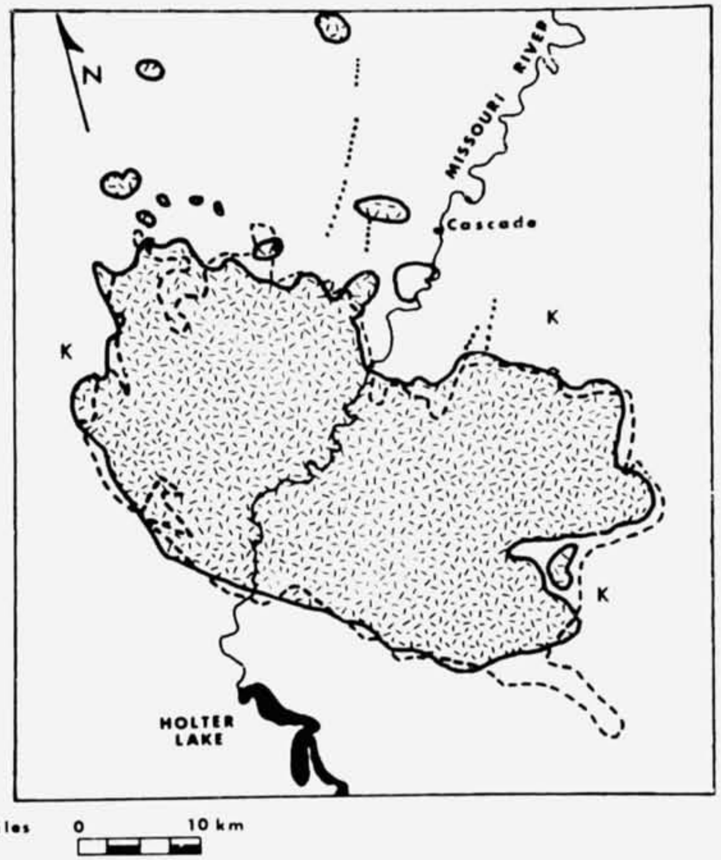


Fig. 2-1 (left). ERTS-1 detail of Adel Mountain volcanic field and Missouri River Canyon. Buttes to north are unroofed laccoliths (1089-17515-7). Fig. 2-2 (right). Contacts of Adel Mountain Volcanics drawn from Fig. 2-1 (solid lines) compared with those of state geologic map (dashed). Dotted lines are dikes. K - Cretaceous sedimentary rocks. Pattern - volcanics.

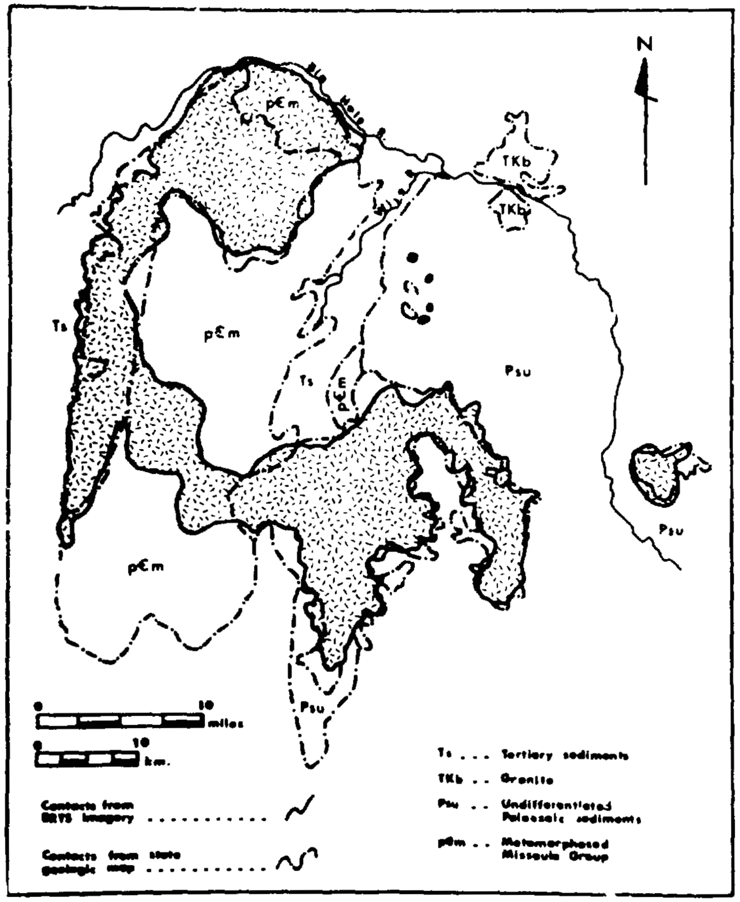


Fig. 3. Granitic contacts in Pioneer Mts. from ERTS imagery (1035-17520-7). Identity of other rock units from state geologic map. Discrepancy in west center will be field checked.

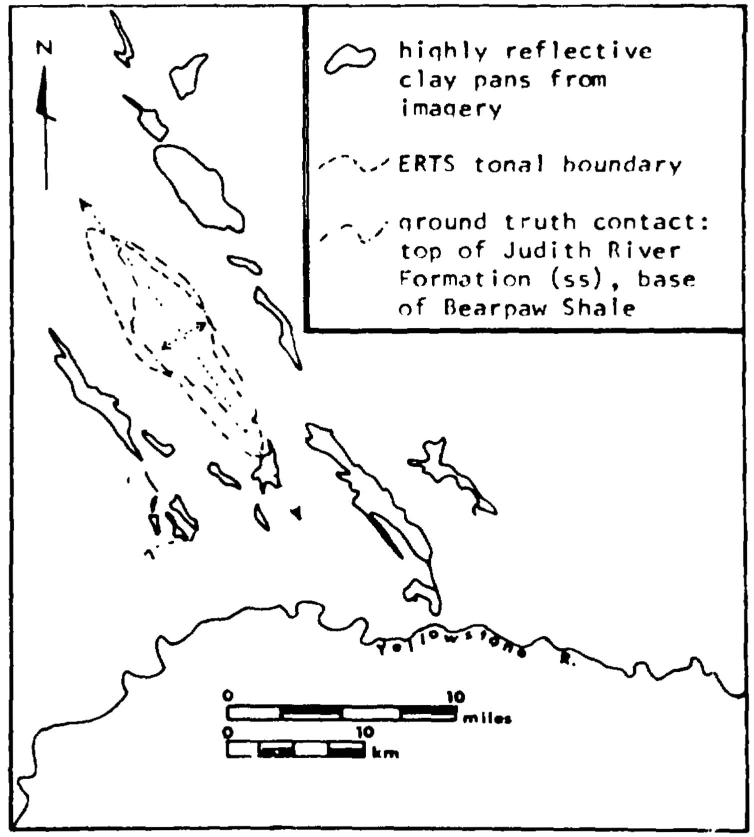


Fig. 4. Imagery map of Ingomar anticline showing sandstone core and clay pans associated with bentonite beds in Bearpaw Shale. Drawn from 1:500,000 scale enlargement (1085-17291-5).