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Geology of central part of the Flathead Range Montana

Lee A. Woodward

The University of Montana

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GEOLOGY OF CENTRAL PART OF THE FLATHEAD RANGE, MONTANA

by

Lee A. Woodward

B.A. Montana State University, 1958

Presented in partial fulfillment of the requirements for the degree of Master of Science

MONTANA STATE UNIVERSITY

1959

Approved by:

R. M. Weidman
Chairman, Board of Examiners

Date

Dean, Graduate School

MAY 28, 1959
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Geologic mapping disclosed three sets of normal faults cutting the Belt series and Paleozoic strata:

1. Longitudinal northwest trending faults dipping to the west, which are parallel to the range and the strike of the easterly dipping strata. The three faults in this set are:
   (a) The Flathead fault, which is a zone up to half a mile wide of gouge, breccia, and large horses along the western edge of the range.
   (b) The Roosevelt fault, which is a zone of gouge and breccia more than 100 feet wide along the eastern edge of the range.
   (c) An intermediate fault marked by a zone of brecciated rock up to 100 feet wide.

2. Transverse northeast trending faults dipping both north and south. These constitute a younger set and displace the two westernmost longitudinal faults.

3. Northwest trending faults that are antithetic and sympathetic with respect to the Flathead fault.

Shear surfaces in a test pit in the Flathead fault zone dip 60° W. Traces of the Roosevelt and intermediate faults indicate dips to the west. West dips of the longitudinal faults are also indicated by their strike separations along the transverse faults, for which normal displacements are known.

Assuming that these faults are orogenically related to the
Lewis overthrust, their normal character implies that they are later in the orogenic cycle than the overthrusting. Some previous investigators have considered the longitudinal faults to be reverse faults dipping to the east. The above data suggest that detailed mapping of other longitudinal faults in surrounding areas may show them to be normal rather than reverse.
INTRODUCTION

LOCATION AND ACCESSIBILITY

The area mapped includes the central part of the Flathead Range, which is located in northwestern Montana. This area covers approximately 125 square miles in Townships 26, 27, and 28 North, Ranges 15, 16, and 17 West, Montana Base and Meridian, and it is included within the Flathead National Forest (South Half). The boundaries of the mapped area coincide with natural physiographic features (see Figure 1 and Plate 1).

U.S. Highway 2 passes through Martin City, which is about 35 miles north of the area under discussion. From Martin City a graveled road leads south along the east shore of Hungry Horse Reservoir and along the western boundary of the mapped area. There are no roads and only two trails that cross the entire length of the Flathead Range, although trails lead part way up several of the canyons on both the east and west slopes of the range. At the present time these trails are poorly maintained and must be cleared of downed timber before pack and saddle animals can get through. The higher ridges and peaks are accessible only by foot or helicopter. The South Fork of the Flathead River and Hungry Horse Reservoir are navigable by small boats, but the Middle Fork of the Flathead can be travelled by boat only with extreme caution because of rapids and boulders in the stream. Field work is limited to the time between May and November because of heavy snowfall.
Figure 1. Index map showing mapped area (shaded) and surroundings.
PURPOSE OF THE INVESTIGATION

The original purpose of the study was to collect geologic data for the U.S. Bureau of Reclamation for use in feasibility studies for dam and tunnel construction. The main area of interest was a relatively narrow zone extending from Spruce Park to the mouth of Hoke Creek. In mapping this zone it was necessary to cover adjacent areas in order to trace and project geologic features into the zone of interest. After the completion of work for the Bureau of Reclamation, the study was continued in the Upper Twin Creek area in order to determine structural relationships there. In this paper emphasis is placed on structural interpretations.

PREVIOUS WORK

In the past the area has been studied only superficially because of lack of economic incentive in addition to the difficulties imposed by brush and overburden, rugged terrain, and a short field season. Most previous investigators have been hampered by covering a very large area in a short period of time. As a consequence most of the geologic maps are of a hasty reconnaissance nature.

Clapp (1932) covered 16,000 square miles in western Montana with widely separated traverses limited to the roads, main trails, and some of the higher peaks. The geology was mapped on a scale of 1:125,000 along the traverses and was extended to the areas between
the traverses.

Erdmann (1947) has covered the western edge of this area in his excellent report on Hungry Horse Dam and Reservoir Site.

The Geologic Map of Montana by Ross et al. (1955) covers this region on a scale of 1:500,000.

The above mentioned maps and reports were of much value to this author during preliminary investigation of the area. Certain reports on adjacent areas, while not dealing specifically with the thesis area, were used to obtain an impression of the regional geologic setting. Among these were Daly's report on the 49th parallel (1912), the stratigraphy and structure of the Lewis and Livingston Ranges by Willis (1902), and Billings' study of the Lewis overthrust (1938).  

PRESENT STUDY

Approximately sixty days were spent in the field between June and October of 1958. Most of the mapping in the northern part of the area was done in conjunction with Mr. R. O. Birch of the U.S. Bureau of Reclamation. Field data were plotted on air photos, U.S. Geological Survey advance prints of Nyack Quadrangle, Montana, U.S. Forest Service Flathead National Forest (South Half) map, and topographic sheets prepared by the Bureau of Reclamation. These data were transferred to a base map of Flathead National Forest (South Half) (1:125,000) enlarged to a scale of 1:63,360. Symbols for roads,
trails, lookouts, and triangulation points were eliminated on the base map, and the contour interval was changed from 200 to 400 feet. Stereo pairs of air photos flown at a scale of 1:36,000 in 1954 and 1955 by the U.S. Geological Survey were obtained through the U.S. Bureau of Reclamation, Denver, Colorado, as was an aerial mosaic that was prepared from these photos by the Bureau of Reclamation.

Most of the mapping was done on foot, however where it was practicable use was made of other forms of transportation including automobile, saddle horse, airplane, and rubber raft.

Much of the information was gained from the ridge crests and higher slopes where vegetation and overburden are more sparse than along canyon bottoms and the lower slopes of sidehills. Faults, contacts, key beds and other pertinent features were plotted on ridge tops and were correlated with adjacent ridges. These geologic features were then extended down and laterally to the valley bottoms.

Stratigraphic thicknesses were obtained mainly by scaling from the geologic map and cross sections, and lithologic descriptions are rather generalized because the reconnaissance nature of the work did not warrant making detailed lithologic descriptions or measuring exact stratigraphic thicknesses.

ACKNOWLEDGEMENTS

The author thanks the U.S. Bureau of Reclamation for permission to use the data collected while in their employ, and for the use of
their facilities and equipment while preparing this thesis. Mr. Rondo O. Birch, Area Geologist, U.S. Bureau of Reclamation is due special thanks for his constructive criticism during the period of field work. The assistance and cooperation of the faculty of the Geology Department of Montana State University is gratefully acknowledged.
PHYSIOGRAPHY

TOPOGRAPHY

The Flathead Range trends somewhat west of north with smaller lateral ridges trending east-west. The range is bounded on the east by the Middle Fork and on the west by the South Fork of the Flathead River.

Figure 2. Air view looking west at the Flathead Range, with Mount Baptiste in the center background. The Middle Fork valley is in the foreground.

Sharp rugged peaks and deep steep-walled canyons are present throughout the area and there is an average relief of approximately 3000 feet (see Figure 2). Mt. Baptiste, the highest point in this part of the range, has an elevation of 8396 feet above mean sea
level. Hungry Horse Reservoir, at 3560 feet above mean sea level, has the lowest elevation in the area. The Middle Fork valley has an elevation of approximately 4100 feet at Spruce Park.

GEOMORPHOLOGY

It is interesting to note that the highest peaks occur in the western part of the range. To the author, this suggests that the scarp on the west side of the range is a fault scarp rather than a fault-line scarp, as will be discussed later under structure.

Mountain glaciation has profoundly affected the landscape at higher elevations. Mt. Baptiste is an excellent example of a horn. Cirques are found at the heads of Hoke, Lower Twin, Bergsicker, and Charlie Creeks. The cirque headwall in Lower Twin Creek has a relief exceeding 2000 feet. Bergsicker and Charlie Creeks flow through textbook examples of U-shaped glacial troughs, characterized by cirques, tarns, trough headwalls, glacial steps, and hanging valleys. Tarns are located also in several of the tributaries of Lower Twin Creek.

The area as a whole is in a mature stage of erosion, with a maximum of steep slopes. There appears to be some rejuvenation along the Middle Fork where a steep-walled canyon has been cut nearly 200 feet into the valley floor downstream from Spruce Park.

Air photos reveal northwest trending lineations in the glacial debris in the South Fork valley. These lineations are up to a mile
in length and several hundred feet wide with a general groove-like appearance and appear to be the result of glacial action.

VEGETATION AND ANIMAL LIFE

The lower slopes have a heavy cover of vegetation but the crests of the ridges and peaks are in general quite bare. Conifers are the most abundant of the trees, although there are many large areas of willows and alders. There is a growth of underbrush in the northern part of the area.

Commercial logging is being carried on near the road along the reservoir, but most of the stand of timber suitable for lumber is at the present inaccessible. Large grassy meadows found in many of the higher valleys are used only as occasional forage for hunting parties. Deer, elk, moose, bear, and mountain goats provide big game hunting and a source of livelihood for packers and guides from nearby areas. Fish are abundant in the streams and reservoir. There are no permanent human inhabitants, and no land is under cultivation in this area.

CLIMATE

Although no climatological data have been recorded in this area, records have been kept about 25 miles to the north at Hungry Horse Dam since 1948. The average temperatures are probably somewhat lower and the average precipitation somewhat higher here than those re-
corded at Hungry Horse Dam. Most of the following data pertaining to Hungry Horse Dam were taken from the U.S. Bureau of Reclamation (1958) and cover the years 1948 to 1957.

The yearly total precipitation has varied from 16.72 inches to 39.27 inches. Erdmann (1947) reports the entire South Fork drainage area averages 26 inches of runoff per year.

This area is characteristic of the Northern Rocky Mountain physiographic province with large seasonal and diurnal variations in temperature. Mean annual temperatures have ranged between 39.0 and 44.9 degrees Fahrenheit. The lowest recorded minimum is -40 degrees and the highest maximum 99 degrees. January is the coldest month with the lowest mean of 2.5 degrees, and July is the warmest with the highest mean of 66.7 degrees Fahrenheit.

DRAINAGE

The two major streams of the area, the South Fork and Middle Fork of the Flathead River, flow north parallel to the strike of the easterly dipping strata and are longitudinal with respect to the major structure of the region. As can be seen on Plate I these streams parallel the Flathead and Roosevelt faults but the South Fork is located west of the Flathead fault, and the Middle Fork is west of the Roosevelt fault (except where the Middle Fork swings to the east).
The tributary streams are in general transverse to the geologic structures giving a rather rough trellis pattern. Glaciers have caused stream derangement on a minor scale at the mouths of Charlie and Long Creeks where new channels have been cut after blockage of the former channels. It appears that the channel of Charlie Creek where it swings north to enter the Middle Fork was superposed as a result of glacial debris filling the original channel which ran due east until it joined Long Creek (see Plate I). Long Creek near its mouth seems to have flowed in a channel about 200 yards east of its present channel, but the cause of its change is not readily apparent. The cause of derangement was probably blockage of the original channel by ice, although there is no proof of this.
REGIONAL GEOLOGY

Northwestern Montana is characterized by broad intermontane valleys and parallel mountain ranges trending approximately N.25°W. (see Figure 8). The mountain ranges are composed of Late Precambrian Belt sediments that strike parallel to the ranges and dip to the northeast. From one range to another the stratigraphic sequence is repeated in Belt rocks that are dominantly argillites, impure limestones, and quartzites. Scattered occurrences of unconformably overlying Paleozoic strata are mainly limestones and dolomites. Most of the larger valleys are Quaternary glacial deposits that occur as lake and stream deposits as well as moraines.

The main regional fold is a synclinorium, the axis of which trends N.25°W., closely coinciding with the Continental Divide, with the east limb dipping much more steeply than the west limb (Clapp, 1932).

Faults are the most outstanding structural features in this region. It is bounded structurally on the east by the Lewis overthrust and a zone of imbricate structure composed of many west dipping thrust faults. Northwest trending faults of major displacement bound many of the mountain ranges (see Figure 8). It is controversial as to whether these faults are normal or reverse. There are other faults in the region that have variable attitudes, but they are comparatively minor in terms of displacement. The Rocky Mountain
trench has been traced southward to the Flathead valley near Kalispell (Eardley, 1951), but its location south of there is conjectural. Daly (1912) suggested that it is a fault zone with a master normal fault. Evans (1932) considers the trench to be located along a zone of opposed thrust faults with the trench thrust down in relation to its surroundings.

Intrusives are notably absent, with the exception of small dikes, sills, and stocks that occur in the Precambrian rocks. The Paleozoic rocks seldom contain intrusives, but in adjacent regions the Mesozoic strata are intruded by diabases that appear to be quite similar to those found in the Precambrian rocks of this region.
Exposed in this area is a thick sequence of argillites, impure limestones, and quartzites that compose the Belt series of Late Precambrian age. Although the individual formations and members vary lithologically from the type section for each, the author has classified these strata in three groups on the basis of lithologic character (see Table I). The boundaries between these groups are transitional and contacts have therefore been chosen more or less arbitrarily by the author. The work of Ross (1954) has been followed in that the Precambrian strata are divided into the Ravalli, Piegan, and Missoula groups.

RAVALLI GROUP

The oldest rocks in the area belong to the Ravalli group and consist of approximately 4500 feet of maroon and green argillites and pink quartzite. The lower 3600 feet are mainly thinly laminated, slightly arenaceous argillites intercalated with thick beds of pinkish quartzite. The upper 900 feet are composed of thin-bedded greenish-gray argillites interbedded with thin laminae of quartzite. Toward the top are a few zones of brownish calcareous argillite. Clapp (1932) states that in this region the Ravalli group is made up of the Grinnell argillite (2000 to 3500 feet thick) and the underlying Appekunny formation, however, the author is unable to establish valid criteria
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<th>FORMATION</th>
<th>THICKNESS (feet)</th>
<th>LITHOLOGY</th>
</tr>
</thead>
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<tr>
<td>Recent</td>
<td>Alluvium</td>
<td>0 to 250</td>
<td>Unconsolidated terrace and floodplain silts, sands, gravel, and boulders; angular fragments in alluvial fans.</td>
<td></td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Glacial drift</td>
<td>0 to 700</td>
<td>Includes both till and outwash. Mainly an unsorted mixture of boulders and rock flour, with some gravel, cobbles and sand. In places rock flour has weathered to clay.</td>
<td></td>
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<tr>
<td>Mississippian, Devonian, and Cambrian</td>
<td>Undifferentiated carbonates</td>
<td>4000</td>
<td>Finely laminated grayish-white limestone with intercalated beds of shale. Brachiopod and coelenterate fossils are sparingly present in the limestone.</td>
<td></td>
</tr>
<tr>
<td>Cambrian</td>
<td>Wolsey shale</td>
<td>200</td>
<td>Greenish shale with interbedded brown sandstone.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flathead quartzite</td>
<td>125, 50, 75</td>
<td>White, coarse-grained thick-bedded quartzite. Thin-bedded, fine-grained, whitish-pink quartzite.</td>
<td></td>
</tr>
<tr>
<td>Missoula group</td>
<td>Undifferentiated</td>
<td>6000 to 22,000 (1)</td>
<td>Maroon, green, and gray thin-bedded argillite with intercalated thin beds of quartzite. Calcareous beds are present in a few instances. Zones of argillite several feet thick alternate with zones of intercalated quartzite and argillite. Zones 10 to 20 feet thick of gray limestone separated by zones 10 to 40 feet thick of thin-bedded brown calcareous shale and sandstone.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Zone</td>
<td>1200</td>
<td>Thin-bedded, maroon and green argillite intercalated with thin-bedded quartzite.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle Zone</td>
<td>1200</td>
<td>Thin-bedded, brownish-gray calcareous shales and ferruginous sandstone. Thin argillaceous limestone beds are in zones up to 10 feet thick.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Zone</td>
<td>3400</td>
<td>Thick zones of thin-bedded argillaceous gray limestone containing stromatolites, intercalated with thin beds of brown calcareous shale.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grinnell and Anpekuny group</td>
<td></td>
<td>Intercalated zones of thin-bedded gray calcareous shale, thin-bedded sandstone, and thin-bedded green argillite.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grinnell</td>
<td>4500</td>
<td>Thin-bedded green and maroon argillite and quartzite occur in zones separated by thick beds of pink quartzite. The base is not exposed.</td>
<td></td>
</tr>
</tbody>
</table>
for separating the group into the formations as described by Clapp.

This group is exposed along the west slope of the Flathead range where the lower beds are truncated by the Flathead fault or are covered by Quaternary glacial material. East of the Roosevelt fault in the vicinity of Long Creek and the Middle Fork the lower beds of the group are again truncated by faulting or covered by glacial material.

PIEGAN GROUP

Conformably overlying the Ravalli group is the Piegan group. There are three fairly well defined zones in this group, with a total thickness of approximately 5800 feet. It is equivalent to what Clapp (1932) has called the Siyeh or Wallace group.

The lower zone, which is about 3400 feet thick, consists dominantly of calcareous material. The bottom 1000 feet is a sequence of intercalated thin-bedded gray calcareous argillites, thin-bedded sandstones, and green argillites. This is followed by a 2000 feet thick series of thin-bedded argillaceous gray limestones with intercalated beds of brownish calcareous shale. Small gray calcareous lenses and nodules occur in the shale. The limestone is characteristically tan weathering, is distinctly banded, and contains stromatolites (see Figure 3).

These stromatolites appear to be *Collenia symmetrica* described by Rezak (1957) in his study of the stromatolites of the Belt series of Glacier Park. This zone is then equivalent to the Siyeh limestone
of Glacier Park. The top of the lower zone consists of about 400 feet of thin-bedded brownish-gray calcareous shale, with some inter-bedded ferruginous sandstone and a few 10 feet thick sequences of thin-bedded argillaceous limestone.

![Stromatolite in the lower zone of the Piegan group.](image)

Figure 3. Stromatolite in the lower zone of the Piegan group. Note the small gray nodules and lenses in the tan rock.

The middle zone which is 1200 feet thick, is dominantly argillitic. The lower 700 feet consists of thin-bedded maroon or red argillite with minor amounts of intercalated thin beds of maroon quartzite and green argillite. This appears to be the "red band" of the Siyeh or is equivalent to the Spokane formation (Erdmann,
1947 and Clapp, 1932). The upper part is a sequence of about 500 feet of thin-bedded gray, green, and black argillite. The black argillite is very hard and resistant.

The upper zone is about 1200 feet thick, consisting of thin-bedded gray limestone with interbedded sequences up to 20 feet thick of brown calcareous shale and sandstone. This zone is equivalent to what has been called in other locations the Helena limestone, Wallace limestone, and Upper Siyeh limestone (Clapp and Deiss, 1931).

The Piegan group crops out along the crest of the Flathead Range, and gradually is faulted out to the south. These strata occur along the lateral ridges on the east side of the range where they are overlain conformably by the Missoula group. A small block of the Piegan group is exposed along the west side of Lower Twin Creek valley along a normal fault. To the east of the Roosevelt fault strata of the Piegan group occur along the ridge east of Long and Grouse Creeks.

**MISSOULA GROUP**

The upper group of the Belt series, the Missoula group, rests conformably on the Piegan. The exact thickness of the Missoula group in this area is not known, as there is not a complete geologic section here. Where the base of this group is exposed the upper part is truncated by faulting, and conversely, where the top of the group is
exposed in contact with overlying Paleozoic strata the lower part of the group is truncated by faulting. However, a minimum thickness would be 6000 feet, and the actual thickness is probably much greater. Erdmann (1947) gives the partial thickness of the Missoula group (not including a thick sill) as 22,200 feet in the vicinity of the North Fork of the Flathead River, about 150 miles north of this area. Lithologically the strata consist of thin-bedded maroon, green, and varicolored argillites with intercalated thick beds of reddish quartzite and some light tan calcareous argillite. Mud cracks and ripple marks are characteristic of this group.

Strata of the group crop out on the lateral ridges bounding Charlie and Bergsicker Creeks and in the area west of the Roosevelt fault between Long and Lower Twin Creeks. These strata are found also west of the Flathead fault and south of Circus Peak.

In the area investigated by the author the contact between the Missoula group and the overlying Paleozoic strata seems to be conformable (see geologic map, Plate I). However, Deiss (1935) has shown in regional studies that an unconformity exists, although in many places it is extremely difficult to detect. Ross (1958) has suggested that part of the Belt series formed synchronously with Cambrian strata elsewhere and that the unconformity, where present, results from a pause in sedimentation and is not a major time gap.
The Paleozoic strata have not been subdivided on the author's map because it is beyond the scope of this paper, however several distinct units are noted. Using thicknesses and lithologies as guides, these units have been tentatively correlated with the Paleozoic section described by Deiss (1933) at Pentagon Mountain, about 17 miles southeast of the mapped area.

The lowermost unit consists of about 125 feet of quartzite and rests unconformably (?) on the Missoula group. The lower 75 feet is composed of thin-bedded, fine-grained, grayish quartzite containing a pinkish zone and some pebbles toward the bottom. The next 50 feet is thin-bedded, coarse-grained, light gray quartzite. This unit is the Middle Cambrian Flathead quartzite described by Deiss (1933).

The next higher unit is a 200 feet thick series of soft, fissile, thin-bedded, greenish-brown shale with intercalated beds of brown sandstone. Some of the shale beds are slightly micaceous. This unit is the Wolsey shale of Middle Cambrian age.

Resting conformably on the shale is nearly 4000 feet of finely laminated, thin-bedded, fine-grained, light gray limestone with a few intercalated beds of shale. This limestone is a very prominent cliff-former and can be recognized quite readily even at a distance. Poorly preserved brachiopod and crinoid fossils were found in a talus slope near the base of the limestone. The brachiopods were identified
as members of the superfamily Atrypacea (ranging from Middle Ordovician to Lower Mississippian). Crinoid columnals were found with the brachiopods. At Pentagon Mountain, Deiss (1933) has measured 3117 feet of Paleozoic strata, most of which is limestone, except for about 250 feet of basal quartzite and shale. 1482 feet of Cambrian, 844 feet of Devonian, and 791 feet of Mississippian strata give a total thickness of 3117 feet. It has been further shown by Deiss (1933) that the Paleozoic rocks of northwestern Montana belong to only the Cambrian, Devonian, and Mississippian systems. Considering these data and the fossil evidence, it seems that Cambrian, Devonian, and Mississippian strata are present in the area mapped by the author.

Figure 4. Looking east at the Paleozoic limestone near Beacon Mountain.
The Paleozoic strata are located on the ridge between Upper and Lower Twin Creeks where the upper part of the section abuts against the Flathead fault. The Geologic Map of Montana (Ross, et al., 1955) shows the above described strata as Cambrian, but as discussed previously, it seems that strata of later systems are present.

CENOZOIC

Glacial drift of Pleistocene age that probably represents different stages or substages is present in both major valleys and several tributary valleys. Differences in texture and the topographic relations of the deposits indicate that the drift is not all of the same age, but a much more detailed study would be necessary to definitely establish the relation of the drift deposits to each other. The drift includes both till and outwash, but no attempt has been made to separate the two. The drift is an unsorted heterogeneous mixture of boulders with cobbles, pebbles, and sand in a matrix of rock flour that is partially weathered to clay. The proportions of the above materials vary from place to place.

In the South Fork valley the drift is found up to an elevation of 4400 feet. Prominent lineations trending N. 25° W. in the drift can be seen on air photos. The exact thickness of the drift here is not known, however information gained during 1958 from drill holes indicates the thickness to be greater than 200 feet near the mouth.
of Hoke Creek.

Drift in the Middle Fork valley probably exceeds 200 feet in maximum thickness in the vicinity of Spruce Park, where a drill hole penetrated nearly 190 feet before entering bedrock. Bergsicker, Charlie, and Long Creek valleys contain fairly small and thin deposits of drift. Glacial debris fills abandoned stream channels near the mouths of Long and Charlie Creeks.

Erdmann (1947) states that near Hungry Horse dam site there are at least two and perhaps three sheets of till or boulder clay, interglacial and postglacial river deposits, and glacial lake beds. He tentatively considers the deposits to be of Kansan, Yarmouth, Illinoian, Sangamon, Wisconsin, and glacial Lake Missoula age.

Recent alluvium is found along most of the important streams of the area as flood plain and terrace gravels that consist of sub-rounded particles of argillite, quartzite, limestone, and igneous rock up to boulder size. Alluvial fans composed of angular fragments occur at the mouths of many of the steep canyons. The alluvium is distinguished from outwash by the fact that the outwash contains a greater percentage of clay size material and is essentially unsorted.
IGNEOUS ROCK AND PETROGRAPHY

The only igneous rock noted by the author is a small pluton (about one mile by one-fourth mile) consisting of tholeiitic diabase that intrudes argillite and calcareous argillite of the Missoula group along Upper Twin Creek in Section 15, T. 26 N., R. 15 W. It is overlain nonconformably by Quaternary glacial drift. The contact of the intrusive and the Belt rocks is very abrupt, with the only effect on the sediments being a bleaching and lightening of color in a zone about 3 feet thick bordering the contact. The steep sides are discordant with the surrounding sedimentary strata. The age of the intrusive can be stated only as pre-Quaternary, however, Clapp (1932) states that in western Montana there have been two periods of intrusion of what he calls gabbro-diorite, during the Precambrian and the Tertiary. It seems probable that the intrusive here is Precambrian.

Megascopic examination with a hand lens indicated the rock to be broadly homogeneous. Study of two thin sections shows the intrusive to be a tholeiitic diabase composed of labradorite (50%), pyroxene (40%), ore (3%), myrmekite (3%), and traces of chlorite, amphibole, and apatite. The pyroxene is mostly pigeonite having a very low 2V. Minor amounts of augite are present. The pyroxene has partially altered to amphibole and chlorite. Myrmekite is a micrographic intergrowth of quartz and sodic plagioclase that fills the interstices between euhedral laths of labradorite and subhedral pyroxene.
STRUCTURE

FOLDS

A structural terrace trending N. 15° W. in the Piegan group at the head of Bergsicker Creek is the only major fold in the otherwise uniformly east dipping strata. A homoclinal dip of approximately 30° is interrupted by this terrace which dips about 5° to the east (see Figure 5). This feature can be traced northward, but it appears to die out to the south. It is about one-fourth mile wide and at least three miles long.

Figure 5. Structural terrace in the Piegan group at the head of Bergsicker Creek.
FAULTS

In terms of magnitude, the faults are the most important structural features and can be considered as belonging to two major sets and one minor set. Of the major sets, the first to be considered is a set of normal longitudinal or strike faults that dip approximately 60° to the west and strike N. 20° W. There is generally considerable dip-slip movement on these faults. The second major set consists of northeast trending normal transverse faults dipping steeply to both the north and south. These faults are generally characterized by minor dip-slip movement.

The minor set consists of normal steeply dipping dip-slip faults that trend N. 70° W. in the general area of the outcrop of the Paleozoic strata. The stratigraphic throw on these faults varies from 200 to 300 feet. The strike of these faults closely parallels the strike of an irregularity in the nearby Flathead fault (see Plate 1).

Longitudinal faults include the Flathead fault on the west side of the range, the Roosevelt fault near Long Creek and the Middle Fork, and an intermediate fault whose trace is seen along Lower Twin Creek and the ridges separating Charlie and Bergsicker Creeks.

The Flathead Fault: This is a zone, up to a half mile wide, containing horses of relatively unbroken rock in gouge and breccia.
The following criteria were used by the author in determining the location and attitude of the Flathead fault:

**Discontinuity of structure:** To the east of the Flathead fault the rocks strike approximately N. 20° W., and to the west of the fault they strike approximately N. 10° E. (see Figure 6).

**Repetition of strata:** Going east in the vicinity of Upper Twin Creek one moves up the geologic section, because the strata dip uniformly to the east. The stratigraphically lower Precambrian Missoula group is exposed east of the Paleozoic rocks, indicating the presence of the fault (see Plate 1).

**Features characteristic of fault planes:** A shear surface dipping 60° to the west in gouge and breccia was observed in a test pit located in Section 18, T. 27 N., R. 16 W. Outcrops of gouge were observed at many locations along the trace of the fault. At numerous places along the fault in rock adjacent to the gouge zones, rock cleavage was seen to dip quite steeply to the west. This cleavage is quite intense near the gouge zones, but dies out about 100 feet away. The author considers these to be incipient shears analogous to sympathetic faults.

**Physiographic criteria:** There is a very noticeable alignment of springs in the area between Hoke Creek and Logan Creek suggesting control by the fault zone. In the area between Logan and Peters Creeks there occurs a series of steeply pitching slopes...
with flat swampy areas at their bases. These swampy areas are well up on the hillsides where one would expect them to be well drained. It is the author's opinion that the pitches are parallel to fault surfaces and the flats are horses in the fault zone. The scarp along the fault in the northern part of the range does not offer positive proof of whether it is a fault scarp, fault-line scarp, or composite fault scarp. Assuming the range to be a fault block tilted to the east, the location of the highest peaks on the western edge seems very much in accordance with the concept of a fault scarp. Also, it is difficult to visualize differential erosion acting in such a manner as to necessarily leave the western edge of the fault block higher than the eastern edge. However, considering that there is no scarp along the fault south of Peters Creek it seems probable that the scarp, where present, is a composite fault scarp that owes its height partly to actual fault movement and partly to differential erosion.

The scarp on the west slope of Crossover Mountain may have been caused by stream erosion or glacial scouring, or both. There is also the possibility that in the South Fork valley there is an unmapped fault that may be a branch of the Flathead fault or a separate fault.

Prominent trenches mark the trace of the fault zone where it
crosses the ridge north of Crossover Mountain (see Figure 6).

Figure 6. Trench trending N. 60° W. in Section 35, T. 27 N., R. 16 W. The strata on the left of the trench strike west of north and the strata on the right strike east of north.

The exact displacement on the Flathead fault cannot be determined from the data available to the author, but it appears that the displacement is less in the vicinity of Upper Twin Creek than near Hoke Creek. There is at least 4000 feet of stratigraphic throw near Upper Twin Creek, and possibly more depending upon the thickness of the Missoula group. Near Baptiste Creek there is a minimum of 6000 feet and a maximum of greater than 20,000 feet of stratigraphic throw.

Dip to the west is shown by the shear surface in the test pit and by the manner in which younger transverse faults of known dip-
slip displacement have offset the Flathead fault.

The Roosevelt fault: This fault was thoroughly studied only in the vicinity of Spruce Park because the effect of the fault on the dam and tunnel sites is limited to that area. Repetition of strata in an area of uniformly dipping strata proves the existence of the Roosevelt fault along the Middle Fork, Long Creek, and Grouse Creek. (See cross sections, Plate 1).

Figure 7. Gouge and breccia in the Roosevelt fault near the mouth of Long Creek.

Features characteristic of fault surfaces are infrequently seen on the Roosevelt fault, however there is an excellent exposure of a zone of gouge and breccia over 100 feet wide near the mouth of Long Creek (see Figure 7). Nearly 300 feet of intensely jointed rock
occur on each side of the fault zone. There is a large horse where the fault zone is exposed along Long Creek in Sections 4 and 5, T. 27 N., R. 15 W. The trace of the fault in this area shows it to dip rather steeply to the west. The stratigraphic throw on the Roosevelt fault at the mouth of Long Creek is approximately 12,000 feet.

The intermediate longitudinal fault: On air photos this fault is discernible as a trench that crosses lateral ridges along the west side of Lower Twin Creek valley. Its trace indicates dip to the west. A stratigraphic throw of about 2400 feet occurs on this fault near Lower Twin Creek, but the throw diminishes to the north to about 400 feet. Along the lateral ridges of Lower Twin Creek valley the Missoula group strata are faulted against strata of the Piegan group. The difference in lithology causes the exposed Piegan limestone to stand out as an "island" surrounded by argillite. A zone of brecciation nearly 100 feet wide occurs where the fault crosses the crests of the ridges separating Charlie, Bergsicker, and Lower Twin Creeks. There is also repetition of Missoula group beds on these ridges as one crosses the fault.

Good exposures show the beds are cut by the fault on the ridge in Section 26, T. 28 N., R. 16 W. At this location a dip of 60° to the west on the fault was measured by sighting across a canyon along the strike of the fault.
The intermediate fault and the Flathead fault appear to intersect near Lower Twin Creek, but it is not at all clear as to whether the intermediate is a branch of the Flathead fault.

**Northeast trending transverse faults**: These are normal faults that dip steeply both north and south. It is probable that more of these faults exist than the 14 shown on the geologic map, for they are frequently difficult to detect without a great deal of detailed work.

The author determined the locations and attitudes of these faults from drag of adjacent strata, outcrops of gouge and breccia, truncation of strata, and displacement of marker beds. Because of the great thickness of lithologically similar strata, it is difficult to select marker beds that will aid in determining minor displacements.

With the exception of the transverse fault in Sections 23 and 24, T. 27 N., R. 16 W., the displacements on the transverse faults are predominately dip-slip and the stratigraphic throws are small, amounting to no more than several hundred feet at the most. The possibility of strike-slip movement on most of these latter faults is eliminated by the fact that many of the transverse faults die out before reaching the intermediate fault. These faults offset the Flathead and intermediate faults. In cases where the displacements of the transverse faults are known, the direction of dip of the longitudinal faults can be determined by the manner in which they are offset.
The right-lateral separation of the intermediate longitudinal fault where it is intersected by the transverse fault in Sections 23 and 24, T. 27 N., R. 16 W. cannot be explained by dip-slip movement alone on the transverse fault. Rather, it appears that the transverse fault has a dextral strike-slip component equal to about half the dip-slip component. The direction of net slip is nearly parallel to the trace of the intermediate fault in the plane of the transverse fault. Furthermore, there is the possibility of rotational movement, causing a greater net slip at the Piegan group-Missoula group contact than at the trace of the intermediate fault.

A set of northwest trending faults: Three normal faults dip steeply both north and south in the Paleozoic strata. Displacements of marker beds indicate stratigraphic throws of between 200 and 300 feet on these faults. There is a small graben between the northern and middle faults. The genetic relationship of these faults to the major longitudinal faults is not known, however it appears that the southwest dipping fault is sympathetic and the northeast dipping ones are antithetic with respect to the Flathead fault. These faults are quite apparent on air photos and are easily spotted from an airplane. Their locations are indicated by drag of beds and zones of brecciation stained by iron oxides.
Faults of unknown dips and displacements have been noted in Section 3, T. 26 N., R. 16 W., and Section 35, T. 27 N., R. 16 W. (see Plate 1). Criteria for determining dips and displacements are lacking, but zones of brecciation show fault traces.

REGIONAL FAULTS

The following discussion is intended to relate the author's findings to the regional faulting (see Figure 8). Clapp (1932) lists the following sets of faults in this region:

1. Steeply dipping strike or longitudinal thrust faults.

2. Low angle overthrust faults.

3. Transverse steeply dipping reverse or thrust faults.

4. Transverse steeply dipping normal or vertical faults.

5. Normal strike faults of low dip.

6. Normal or Basin Range faults, which are not readily distinguishable because their movement appears to have taken place largely along older faults.

The strike or longitudinal faults at the west bases of the parallel mountain ranges are considered by Clapp (1932) to be steep east dipping thrusts that are the oldest faults in the region. The vertical displacements on these faults range from 10,000 to 30,000 feet. These faults have usually been named for the mountain range with which they are associated. Erdmann (1947) has suggested that
these faults may be younger than the west dipping overthrusts. Bailey Willis in his report on the Lewis and Livingston Ranges (1902) considers the longitudinal fault separating the Livingston Range from the Flathead valley to be a normal fault dipping to the west. Willis has fixed the date of the normal faulting as Miocene or Pliocene from tilted lake beds in contact with the fault, and he considers the Lewis overthrust to be older than the normal fault. Pardee (1950), using physiographic criteria, has stated that many of the longitudinal faults are normal and bound tilted fault blocks. He suggests that movement on these faults has continued through Late Tertiary time, and in some cases into the Quaternary.

The low angle overthrusts are typified by the southwest dipping Lewis overthrust whose trace is mainly east of the Continental Divide. Rocks of Belt age have been thrust up and over Mesozoic strata giving a stratigraphic throw of approximately 40,000 feet (Clapp, 1932). As stated previously, Clapp considers these low angle overthrusts to be younger than the longitudinal faults. Alden (1932) has shown conclusively that the Lewis overthrust occurred during Eocene time. It has been suggested by Erdmann (1947) that the Lewis overthrust may underlie the Flathead Range and South Fork valley, but positive evidence of this is lacking.

Transverse steeply dipping reverse or thrust faults are said by Clapp to be fairly numerous in most places where detailed mapping
has been done although there are undoubtedly large areas where these faults are absent. In general the trend of these faults is N. 20° E.

The transverse steeply dipping normal or vertical faults described by Clapp are major faults that form the north and south boundaries of the Paleozoic rocks found in the South Fork valley. The northern fault of this set is apparently the bend in the Flathead fault near Lower Twin Creek.

Normal strike faults of low dip are rather rare, but one has been found to cut the Flathead fault north of the area mapped by the author. The throw on this northeast dipping fault amounts to no more than a few hundred feet (Clapp, 1932).

Normal faulting of Basin Range type has taken place along the earlier longitudinal thrust faults, according to Clapp. The controversial Rocky Mountain trench has been traced as far as Kalispell, but its course south of there is not known. Daly (1912) has suggested control by a master normal fault, but Evans (1932) has suggested it is a zone of opposed thrust faults.
Figure 8. Surface tectonic map of northwestern Montana, modified after W.J. McMannis (1959).
SUMMARY OF STRUCTURAL HISTORY

The thickness and lithologic character of the strata of the Late Precambrian Belt series indicate deposition in a geosyncline. Ripple marks and mud cracks indicate shallow water deposition of the quartzites, argillites and impure limestones.

In this area the lowermost Paleozoic strata appear to overlie the older rocks conformably, but regional studies by Deiss (1935) show that the Cambrian beds rest unconformably on the strata of the Belt series. The nature of this gentle regional angular unconformity indicates that the area was undergoing mild warping at the close of Precambrian time. During the Paleozoic era a geosyncline was again present and a great thickness of limestone and dolomite was deposited.

This region was epeirogenically uplifted and subjected to erosion during early and middle Mesozoic time, but during the late Mesozoic it was probably receiving sediments that were later eroded during early Tertiary time.

It is the author's belief that the structural terrace trending to the north is older than the faulting, but there is no evidence of its age relation to the faults. Folding seems to be more logically associated with overthrusting than normal faulting, and it would seem that the overthrusting occurred earlier than the normal faulting, as will be discussed later.

Although it can be readily seen that the longitudinal faults
are older than the transverse faults, their ages can be determined in this area only as post-Paleozoic and pre-Recent. Regional studies by other investigators indicate a Tertiary age in general, but the age of these faults relative to the Lewis overthrust is controversial. This controversy is based in part on the nature of the longitudinal faults; those persons considering the faults to be reverse favor a pre-overthrust age, while those considering the faults to be vertical or normal favor a post-overthrust age. Clapp (1932) states that the longitudinal faults are upthrusts, i.e., reverse, and are pre-overthrust, while Erdmann (1947) has suggested that the Flathead fault may be younger than the overthrusts. The data collected by the author in this area clearly indicate that the longitudinal faults are normal. Assuming that these faults are orogenically related to the overthrusting and that they have not undergone reverse movement prior to normal movement, it is difficult to visualize these normal faults occurring earlier in the orogenic cycle than the overthrusting. It would seem much more logical for the overthrusting to be followed by relaxation of compressional forces with resultant adjustments by normal faulting. The age of the Lewis overthrust has been shown by Alden (1932) to be Eocene, thus giving a reference point for the age of the longitudinal faults. Willis (1902) has stated the age of the longitudinal fault to the west of the Livingston Range to be Miocene or Pliocene, and as this fault appears to
be an extension of the Roosevelt fault, it shows the latest displacement on the Roosevelt fault to be younger than the Lewis. Pardee (1950) considers the Flathead and other longitudinal faults to be normal and of Late Tertiary age.

The minor normal faults in the Paleozoic rocks do not intersect any other set of faults and their relative ages can not be determined, but it seems to the author that these faults are nearly contemporaneous with the Flathead fault and can be considered sympathetic and antithetic faults (with respect to the Flathead fault).

The transverse faults are obviously younger than the longitudinal faults, because they have offset the latter. The age of the small intrusive along Upper Twin Creek can be stated only as pre-Quaternary, however it seems probable that it is Precambrian (Clapp, 1932 and Ross, 1958).
Minor mineralization occurs within the Flathead fault zone, but at the present there are no commercial operations in the area. Section 17, T. 27 N., R. 16 W. along Hoke Creek is the site of an abandoned prospect. Other instances of very minor copper and gold mineralization were noted along the trace of the Flathead fault zone.

Large quantities of aggregate and impervious glacial material occur in both the South Fork and Middle Fork valleys. These materials appear to be suitable for use in construction. Bedrock is present nearly everywhere and much of it is acceptable as construction material, although in places joints are so closely spaced that the fragments would be too small for use as riprap.
CONCLUSIONS

It can be seen from the following data that the longitudinal faults are normal and dip to the west:

1. In each case the block to the west has moved down relative to the block on the east.
2. A shear surface in a test pit in the Flathead fault zone dips to the west.
3. Traces of the Roosevelt and intermediate faults indicate west dips.
4. The manner in which the trace of the Flathead fault has been offset by transverse faults with dip-slip displacement indicates dip to the west.

Clapp (1932) described the Flathead and Roosevelt faults as east dipping reverse faults, but he suggested that later normal faulting of the Basin Range type may have occurred on older reverse faults. The author has seen evidence of only normal faulting and has no basis for presupposing earlier reverse faulting here although it is possible that the latest movements on the faults have masked the effects of earlier movements.

The Flathead and intermediate faults are the oldest in the area and have been offset by younger transverse faults. The relative age of the Roosevelt fault is not known as it has not been observed to intersect any other fault in the mapped area. However,
it seems reasonable to suppose the Roosevelt fault is the same general age as the Flathead and intermediate faults.

The northwest trending faults in the Paleozoic strata appear to the author to be nearly contemporaneous with the Flathead fault. Assuming that the longitudinal faults are orogenically related to the overthrusting of early Tertiary age, the fact that these faults are normal implies that they are later in the orogenic cycle than the overthrusting. The result of this study suggests that detailed mapping of other longitudinal faults in nearby areas may show them to be normal rather than reverse.
REFERENCES CITED


