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Geology of the southwest Pleasant Valley quadrangle Montana

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GEOLOGY OF THE SOUTHWEST PLEASANT VALLEY QUADRANGLE, MONTANA

by

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ABSTRACT

The area of study embraces 200 square miles in the Selish Mountains of northwestern Montana 30 miles west of Kalispell. Bedrock consists of about 16,000 feet of Precambrian Belt Series rocks including the upper 4,500 feet of the Prichard Formation, 10,000 feet of the Ravalli Group and the basal 1,500 feet of the Piegan Group. The Prichard Formation consists mainly of medium-gray argillite with minor calcareous beds at the top. The Ravalli Group consists of interbedded argillite, fine-grained quartzite, and intermediate gradations between these compositions; three informal subdivisions of this group are recognized. The Piegan Group consists of argillite and quartzitic argillite, both of which types are calcareous in about 50 percent of their occurrences. Belt Series rocks are correlated with units in the Coeur d'Alene district, Libby Quadrangle and Glacier Park.

A low grade of regional metamorphism is indicated in the Belt rocks by the development of sericite, chlorite, and biotite, and by the recrystallization of quartz grains. The Prichard Formation and the two lower units of the Ravalli Group are classified in the quartz-albite-epidote-biotite subfacies of the greenschist facies and the upper Ravalli unit and the Piegan Group rocks are of the quartz-albite-chlorite-muscovite subfacies.

Structurally the area is characterized by broad open folds of northerly trend. Several longitudinal faults of small displacement and a transverse fault with about 2,500 feet of displacement were mapped. These structures are believed due to Laramide orogenic movements, although it is possible that some deformation may be of late Precambrian age.

During Pleistocene time the Cordillerean Ice Sheet covered the area. On the higher slopes remnants of older till consist of granitic boulders derived from Canada. Younger till of large blocks of Belt rocks in a silt and clay matrix floors the valleys and forms dams for the lakes found in the area. Lacustrine silts and clays in the southern half of the area are related to recession of the ice.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The map area, which comprises the southwest 15 minute quarter of the 30 minute Pleasant Valley Quadrangle, includes 200 square miles of the Selish Mountains in northwestern Montana, 30 miles west of Kalispell (Figures 1 and 2). It is bounded on the west by 115th meridian and on the south by 48th parallel. The area occupies a portion of the Kootenai National Forest and, in the northeast corner, a small section of the Flathead National Forest.

The quadrangle is accessible via U. S. Highway 2, which passes through the south half of the area. Secondary Forest Service roads and temporary logging roads are present but are confined to the valleys and mountain slopes. The ridges must be reached by foot. Several Forest Service trails are present in the area but most of them are poorly maintained and must be cleared of downed timber before pack and saddle animals can pass through. Due to heavy snowfall, accessibility of the ridges is limited to the months of June through September.

TOPOGRAPHY

The map area is situated in the Selish Mountains (Figure 2), which extend from the Tobacco River on the north to a point southwest of Flathead Lake. They are bounded on the east by the Flathead valley, which forms part of the Rocky Mountain Trench, and on the west by the Kootenai River and Fisher River. The Selish Mountains trend north-northwest, paralleling the regional structure. Within the mapped area these mountains are comparatively rugged and heavily forested (Figure 3). Most of the area is drained by westerly flowing tributaries of the Kootenai River,

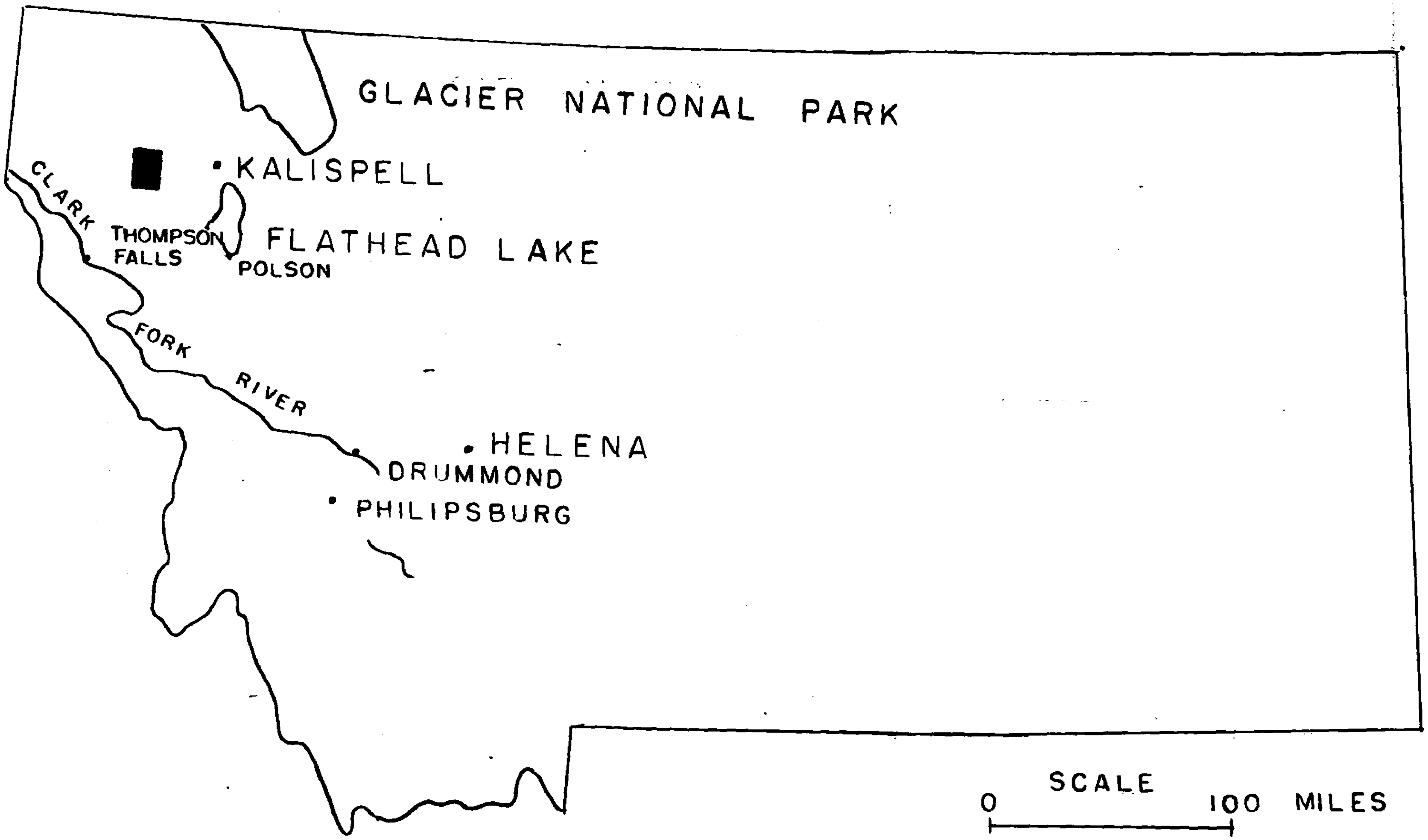


Figure 1. Index map of Montana showing mapped area (shaded) and surroundings.

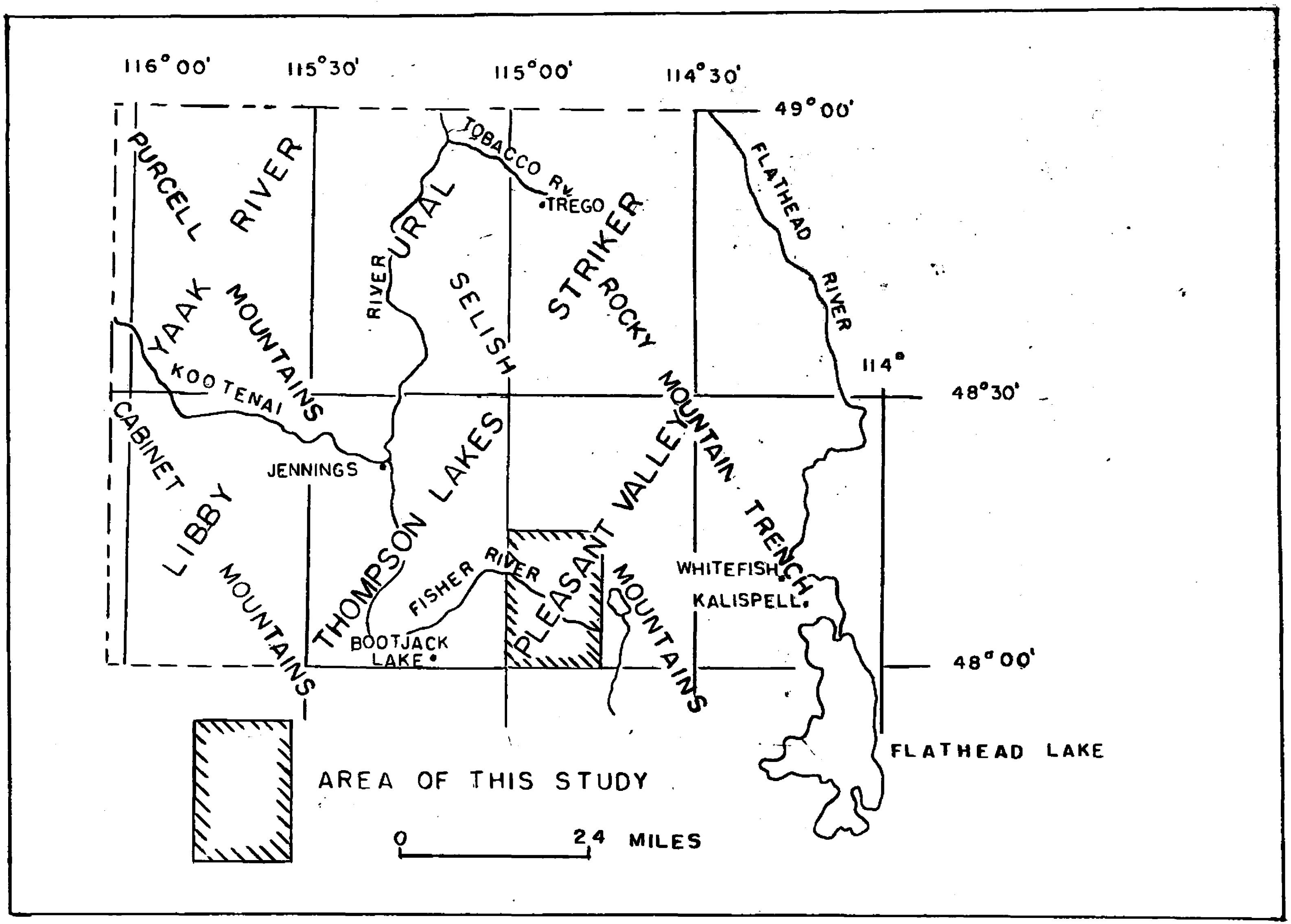


Figure 2. Map of northwestern Montana showing location of quadrangles and physiographic features.

although about 10 square miles in the northeast corner are drained by a tributary of the Flathead River, located to the east.

Figure 3. View looking southwest from Lost Prairie Valley. Meadow Peak is in center right.

Major ridges rise to an average elevation of 5,100 feet, and a maximum elevation of 6,450 feet is attained at Meadow Peak (Figure 3). Where sedimentary beds are nearly horizontal steep cliffs have developed. Main stream valley floors average half a mile in width and reach a depth of 1,000 feet to 2,650 feet below the adjacent ridge tops. Stream gradients locally exceed 300 feet per mile. The lowest elevation is 3,400 feet at the point where McGregor Creek leaves the mapped area. Most of the wider valleys are floored with glacial material, much of which has not been reworked sufficiently by the streams to obliterate the faceting of the pebbles and boulders.

CLIMATE AND VEGETATION

Temperature and precipitation records for the Flathead Valley were obtained from the U. S. Weather Bureau at the Kalispell Airport. Mean annual precipitation for the Kalispell area between 1921 and 1950 was 16.38 inches. The mean annual temperature for a 30 year period was 43.2°F. The highest temperature recorded in the last 40 years was 104°F in 1960 and the lowest was -38°F in 1950. Snowfall averaged 68.3 inches during an 11 year period. It is assumed that precipitation in the mountains of the map area is greater than in the Flathead Valley.

Mountain slopes throughout the map area are forested with ponderosa pine, spruce, larch, and, following logging, with a secondary growth of fir and lodgepole pine. Densest growth is present on the north slopes, and thickets of brush are generally present on all but the highest slopes. On the rocky ridges and in the larger valleys the country is more open; the wider valleys provide grazing for cattle. Logging is actively carried on throughout the map area.

PREVIOUS WORK

Previous geological work covering the map area is limited to a reconnaissance survey of Pleistocene glaciation made by Alden (1953). In nearby areas Gibson (1948) mapped the geology of the Libby Quadrangle and Johns recently completed reconnaissance geological surveys of the south half of the 30 minute Yaak River Quadrangle (1959), the 30 minute Thompson Lakes Quadrangle (1960), the south half of the 30 minute Ural Quadrangle and the northern half of the Yaak River Quadrangle (1961), and the two 15 minute quadrangles in the east half of the Pleasant Valley Quadrangle (1962). Shelden (1961) mapped the northwest 15 minute Ural

Quadrangle and Sommers (see Johns, 1961) mapped the northeast 15 minute Ural Quadrangle. Hall (1962) mapped the northwest 15 minute Pleasant Valley Quadrangle (Figure 2). Lambert's geological reconnaissance of Lincoln and Flathead Counties made during compilation of the State Geological Map (1955) may have covered parts of the area.

FIELD WORK

Reconnaissance geologic mapping was done during the months of June, July and August, 1961. Geology was plotted directly on Forest Service planimetric maps (2 inches to the mile) by inspecting topography and drainage, often with the aid of aerial photographs. All major ridges in the area were traversed and formational contacts were projected between traverses. Although geologic field work was handicapped by a cover of soil, vegetation and glacial drift, location of formational boundaries is considered to be reasonably accurate. A rock color chart published by the Rock-Color Chart Committee of the Geological Society of America was used to standardize rock color descriptions.

ACKNOWLEDGMENTS

Acknowledgments are due to the Montana Bureau of Mines and Geology for financing the field investigation and making available rock chemical analyses, and to Mr. Willis M. Johns, Montana Bureau of Mines and Geology, for acquainting the writer with the Belt stratigraphic section. The writer is greatly indebted to Dr. Robert M. Weidman, Montana State University, for helpful criticism and discussion of the manuscript and other phases of the investigation and to Assistant Professor Arnold Silverman for critically reading the manuscript.

PHYSIOGRAPHY

GEOMORPHOLOGY

The mapped area is within the extensive mountainous region that characterizes large parts of northwestern Montana and central and northern Idaho. Specifically, it lies west of the Rocky Mountain Trench in the central part of the Selish Mountains (Figure 2). In the mapped area the mountains trend northwest with small lateral ridges trending east-west. The flanks of these comparatively rugged mountains dip gently to the valleys. Mature topography is the result of preglacial stream erosion modified by the effects of the Cordillerean Ice Sheet. The drainage pattern is dendritic. The major valleys are Lake Valley, trending somewhat east of north; Pleasant Valley, occupied by the upper Fisher River and trending northwest; the valley west of Dahl Lake and the McGregor Lake Valley, both trending east. The last three valleys are transverse to the major structure, possibly being superposed on the structure or developed along zones of weakness in the rocks that correspond to fractures or shear zones without significant displacement. Such shear zones might be related to the transverse fault in the valley of Dahl Lake. Lake Valley is a strike or subsequent valley that coincides with the weak, readily eroded Belt rocks of the Prichard Formation.

West of the mapped area are the Cabinet and Purcell Ranges. Except for parts of the Cabinet Range, these mountains present topographic characteristics similar to the Selish Mountains described in the area investigated in this study.

The physiographic history of northwestern Montana is traced by Anderson (1929, p. 747-764) back to the uplift originated by Laramide orogeny in late Cretaceous or early Tertiary time. The gradual rise of the mountainous region halted sufficiently to permit the formation of a surface of moderate relief, which reached a stage of maturity in late Tertiary time. Regional rejuvenation in late Tertiary and Pleistocene time resulted in the development of the present topography by stream erosion and glaciation (Ross, 1959b, p. 114).

GLACIATION

At times during the Peistocene, the Cordillerean Ice Sheet covered the mapped area, and probably a large part of northwestern Montana, with variable ice thicknesses. According to Ross (1959b, p. 116) glacial striae along the flanks of the Flathead Valley indicate that the ice was probably over 3,000 feet in maximum thickness in that area. Daly (1912, p. 535) suggests that the ice in the Rocky Mountain Trench at the 49th parallel was about 5,000 feet thick. On the basis of glacial striae observed at elevations of up to 5,500 feet (Figure 4) the ice reached a thickness of at least 2,000 feet over the lower parts of the mapped area. Glacial striae at higher elevations, commonly occupied by softer argillites of the Piegan Group, may have weathered away.

Studies by Alden (1953) indicate there were several stages of glaciation in western Montana, but only in a few places is it possible to clearly differentiate earlier deposits from those of the late or Wisconsin stage of glaciation. In the mapped area it may be possible to discern two ages of glacial till. Older till may be recognized by the occurrence of rounded quartz monzonite erratics on the slopes and higher elevations of the ridges. The lack of such plutonic bed rock in the region leads the writer to agree with Shelden's conclusion (1961, p. 6)

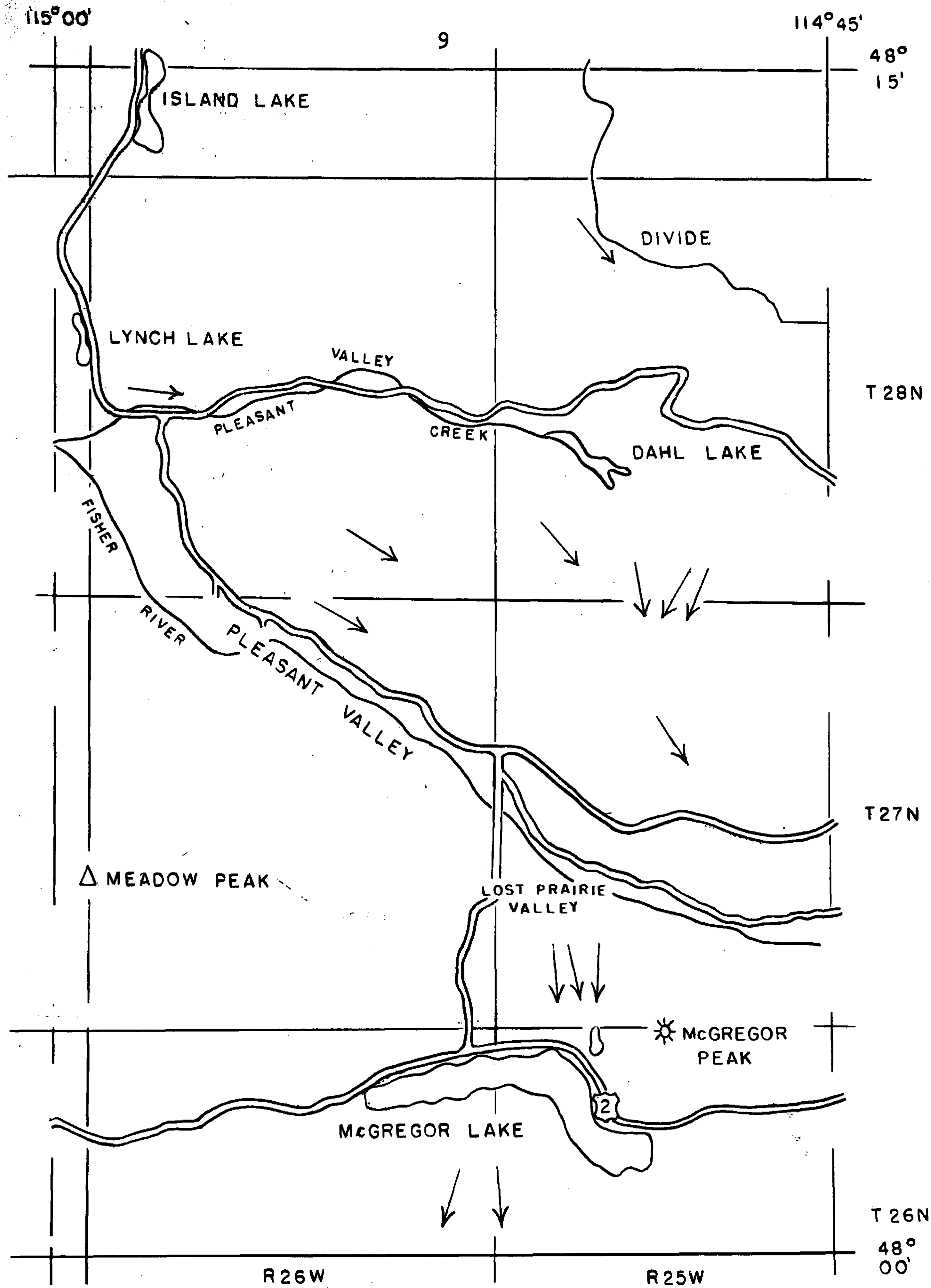
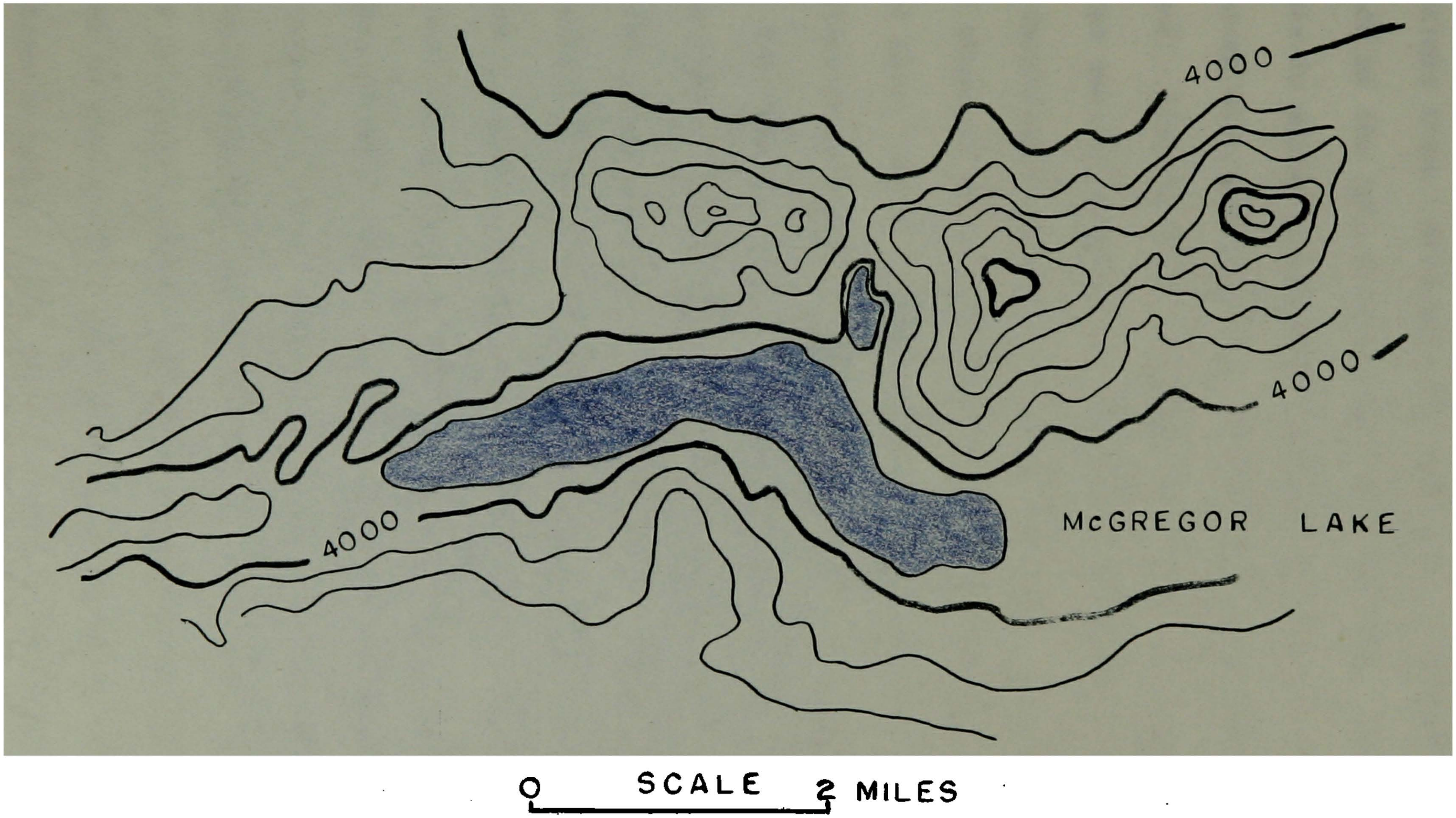


Figure 4. Sketch showing direction of glacial striae in mapped area.

that quartz monzonite erratics originated from acidic igneous plutons present in the Selkirk Mountains in Canada, about 100 miles north of the mapped area. Younger till, which floors the valleys and dams the lakes found in the area, consists of large angular blocks of locally derived Belt sediments in a matrix of silt and clay.

In the area of study morainal heterogenous till is recognized east and west of McGregor Lake and separates Little McGregor Lake from the main body of water. This morainal material dams McGregor Lake, which has the topographic character of a drowned valley (Figure 5). The shore is constituted, in part, by steep slopes and in part, by more gentle slopes or shelving beaches of shingle. One possibility presented by Alden (1953, p. 135) for the origin of the morainal dams is an ice lobe advancing eastward from the valley of the Thompson River to the present McGregor Creek Valley and depositing the east end moraine of the lake and on receding the west moraine. The writer did not find evidence in the field that would support this theory, as no glacial striae were found on the bed rock along the valley walls. Also the valley west of the lake does not have the features common to a glacial trough. Another possibility advanced by Alden and one favored by the writer is an ice advance southward through saddles in the hills immediately north of McGregor Lake. Such an advance could have deposited the till at each end of the lake. This glacial ice could have diverged from the Great Flathead Glacier when it still had a sufficient ice depth in a late stage of glaciation to push a tongue from Trego (Figure 2) southward along Fortine Creek, over a divide (3,900 feet elevation) and down into Wolf Creek and Pleasant Valley as far as McGregor Lake. South of Lost



CONTOUR INTERVAL 200 FEET

Figure 5. Topographic map of McGregor Lake area

Prairie Valley the ice had to reach a minimum elevation of 4,100 feet before it could flow over the hills and down to the basin now occupied by McGregor Lake. (Note the two saddles in north part of Figure 5) Glacial striae found by the writer on these hills indicate that there were ice flows across them. Although the shapes of the moraines at the east and west ends of the lake are not very well defined, hints of curvatures visible in aerial photographs suggest that ice filled the lake basin and moved east and west from the center, depositing low moraines at either end. Alden's third assumption, that an ice lobe extending westward from the Ashley Creek branch of the Great Flathead Glacier could have deposited the east moraine of the lake, is not supported by the present shape of the moraine. Moraines forming dams on the west side of Dahl Lake, the south side of Lynch Lake and the south and east sides of Island Lake are believed to be additional deposits of the ice tongue that diverged at Trego. These moraines are expressed topographically as low curved ridges segmented by drainage outlets.

Glacial lobes advancing down the Purcell Trench blocked the valley of the Clark Fork River and formed a dam 2,000 feet or more in height (Gibson, 1948, p. 55). The resulting lake formed in the Clark Fork Valley was designated Glacial Lake Missoula by J. T. Pardee (1910). The north boundary of this lake along the valley of the Thompson River is not known with certainty. The lake may have expanded across the divide at Bootjack Lake (3,350 feet above sea level) (Figure 2) just west of the map area, or it could have been blocked by an ice dam at this point. Accumulations of horizontally laminated buff-colored, silt and clay indicate deposition in one or more glacial lakes in the southern part of the map area when the ice receded. Such deposits were observed along the Fisher River in the southwest part of the area and along U. S. Highway 2 (Figure 6). The slopes of the hills surrounding McGregor Lake are also covered by silts and clays. The evidence points to the presence of one or more proglacial lakes that occupied the valleys in the south half of the area. Since lacustrine deposits were not observed in the valleys of the northern half of the study area, it is assumed that the ice formed a barrier on the north. On the other hand it is possible that lacustrine deposits in that area may have been eroded away. According to Alden (1953, p. 134-136) local proglacial lakes expanded in the headwater tributaries of the Fisher River, forming them into a single branching lake. The lake or lakes that occupied the southern half of the mapped area may have been of Alden's proglacial type or an extension of Glacial Lake Missoula.

Figure 6. Stratified lacustrine silts 3 miles west of McGregor Lake on U. S. Highway 2.

REGIONAL GEOLOGY

Northwestern Montana, as treated in this paper, embraces that part of the state west of the eastern front of the Rocky Mountains as far south as the line through Thompson Falls and Polson (Figure 1). The region is characterized by a sequence of mountain ranges and parallel valleys that trend essentially northwest.

In part of the region the rocks belong chiefly to the Precambrian Belt Series, which consists mainly of argillite, quartzite and impure limestone. Most of the larger valleys are floored by Quaternary glacial and alluvial deposits in form of river gravels, lacustrine silts and glacial debris.

Evidence gathered by Maxwell (1959) southwest of Drummond indicates that there was some deformation of the Belt sediments prior to the deposition of Cambrian rocks. However, most geologists believe that the major deformation of the Belt rocks is related to the Laramide orogenic movements in Mesozoic or early Tertiary time which folded the rocks and displaced them along extensive faults. Folds and faults generally trend northwest. Outstanding structural features of the region are the Lewis Overthrust in Glacier National Park and the Rocky Mountain Trench. The Lewis Overthrust, along which Precambrian Belt rocks were thrust eastward over Mesozoic shales and sandstones, has been shown by MacKenzie (1916) to be Eocene in age. The Rocky Mountain Trench is a remarkably flat depression that extends from the Flathead Valley northwestward for about 800 miles. Daly (1912) has suggested that the trench is a fault zone with a normal master fault. Evans (1933) states that the trench was formed by overthrusting and overturning towards the trench, with the trench thrust down in relation to its surroundings.

STRATIGRAPHY

Northwestern Montana is underlain by an extremely thick sequence of strata that belong to the Belt Series of Precambrian age. The Series includes assemblages of argillites, quartzites, intermediate gradations between these compositions, and carbonate rocks. Shallow water features such as oscillation and current ripple marks, mudcracks, and cross-bedding are abundant. Most of these Belt rocks have suffered low grade metamorphism. Although some show shaly fissility, slaty or schistose cleavage was not observed in the mapped area.

C. P. Ross (1959a, p. 6) has tentatively classified the Belt Series rocks in Glacier National Park into three groups to facilitate correlations. In ascending order these groups are the Ravalli, Piegan and Missoula (the last named does not occur in the area of this study). Gibson (1948) suggests from studies in the Libby Quadrangle, that strata below the Ravalli rocks correlate with the Prichard Formation, described by Calkins and MacDonald (1909) in northern Idaho and northwestern Montana. Ross (1959a) believes that detailed studies of rocks below the Ravalli Group west of Glacier National Park will result in the recognition of several map units, which may later be embraced in a group. Johns (1959-1961) mapped the rocks below the Ravalli Group in nearby areas as broadly equivalent to the Prichard Formation and placed them under the heading "Pre-Ravalli Group". Rocks below the Ravalli Group have not been subdivided in the map area. They are lithologically similar to rocks mapped as Prichard Formation to the west, and are therefore included under the heading "Prichard Formation" throughout this paper.

The Ravalli and Piegan Groups have not been formally subdivided between the Rocky Mountain Trench and the Idaho border. An attempt will be made in this paper to suggest three possible subdivisions of the Ravalli Group. In northwestern Montana, excluding the area east of the Rocky Mountain Trench and Flathead Lake, post-Beltian sediments have been completely eroded except where locally trapped and preserved by faulting. Both intrusive and extrusive basic igneous rocks of late Precambrian to Cambrian age and intrusive rocks of Mesozoic age (Gibson, 1948) occur in the region but not in the mapped area. Pleistocene glacial debris occurs in all of the larger valleys.

All consolidated strata in the Southwest Pleasant Valley Quadrangle are part of the Belt Series (Table 1). They total approximately 16,000 feet in thickness and comprise, in ascending order, the Prichard Formation, Ravalli Group and the Piegan Group. Neither the base of the Prichard Formation nor the top of the Piegan Group are exposed. Unconsolidated Quaternary sediments include widely distributed Pleistocene glacial silts, clays and till.

For the most part, the Belt section is poorly exposed and presents a mapping problem because of its lack of fossils, poor marker horizons, and difficulty in obtaining continuous descriptive sections. Since most of the formational contacts are gradational in the lower Belt Series, local uncertainties as to the precise position of boundaries are inevitable. The thicknesses of rock units are approximate because they were obtained by plotting structure sections based on the geologic map.

PRICHARD FORMATION

Oldest strata in the mapped area belong to the Prichard Formation which was named by Ransome (1905, p. 281) in the Prichard Creek area of

Table 1. GENERALIZED STRATIGRAPHIC SECTION OF BELT STRATA IN THE SOUTHWEST PLEASANT VALLEY QUADRANGLE

Nomenclature	General Lithology	Thickness (feet)
	Top eroded	
Piegan Group	Greenish-gray, purplish-gray quartzitic argillite. Thin-bedded and mud cracked, locally calcareous.	1,500 ±
Ravalli Group	Light gray to white, purple-banded quartzite and argillaceous quartzite, 3,500 ± feet thick. Medium-bedded light-gray to medium gray argillite and argillaceous quartzite with biotite and magnetite, 4,500 ± feet thick. Greenish-gray argillite and quartzitic argillite with abundant biotite, 2,000 ± feet thick.	10,000 ±
Prichard Formation	Banded blue-gray and medium gray argillite and quartzitic argillite, minor calcareous beds at the top. Commonly contains biotite and sparse pyrite.	4,500 ±
	Base not exposed	

northern Idaho. Only the upper 4,500 feet of the Prichard Formation are exposed in the northwest corner of the mapped area, where the lithology is very consistent. The rocks are mainly banded argillites in hues of medium to dark blue-gray. The bands average about one quarter of an inch thick. Occasionally thin beds of medium-gray quartzitic argillites are found interbedded with the argillites. The Prichard rocks contain an abundance of biotite and sparse pyrite. They have shaly partings in places. Shallow water features are notably absent except for a few ripple marks observed in the uppermost horizons. The rocks show a typical red-brown color on weathered surfaces, which resulted from the oxidation of the iron bearing minerals (Figure 7). Beds vary from less than one inch thick to a rare maximum of 2 feet thick.

A calcareous member was found near the top of the Prichard Formation throughout most of the contact zone. This member consists mainly of a calcareous argillite banded in light shades of gray and bearing abundant biotite and sparse pyrite (Figure 8). Its thickness is estimated to be between 15 and 20 feet. Bedding thickness varies from a few inches to about one foot thick.

Petrography. Three thin sections of the Prichard rocks were observed under the petrographic microscope (See Appendix). They show a fine-grained character with original textures somewhat obscured by recrystallization. Post depositional fractures about 0.30 millimeter wide were observed cutting across the bedding. Except for the calcareous argillite, the fractures are commonly filled with quartz and hematite, which could have been hydrothermally introduced into the rock or remobilized from the matrix to the fractures during recrystallization. Two

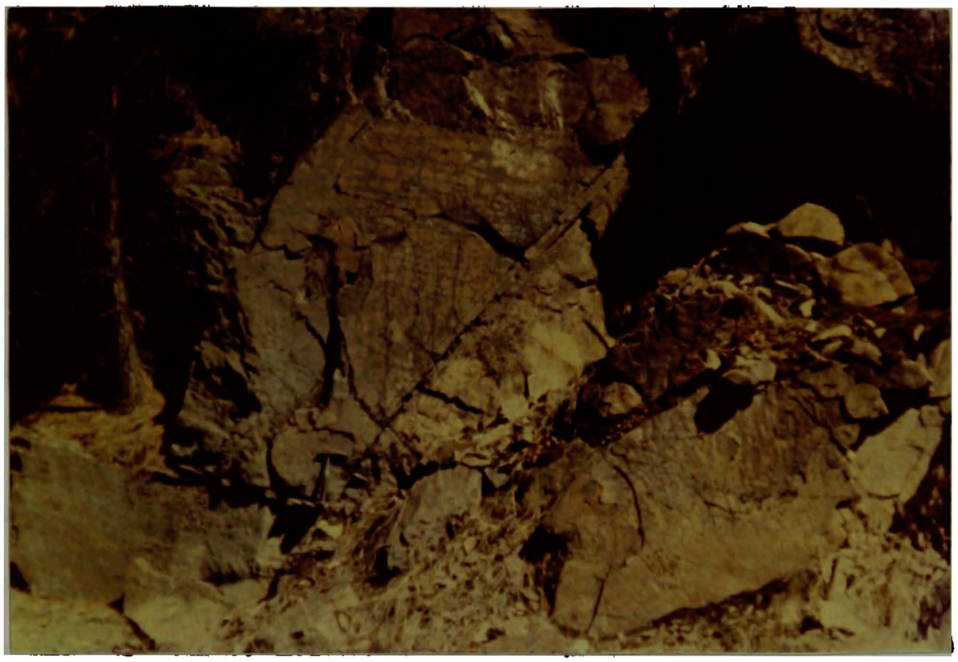


Figure 7. Prichard argillite exposed along Lynch Lake road showing typical red-brown weathering.

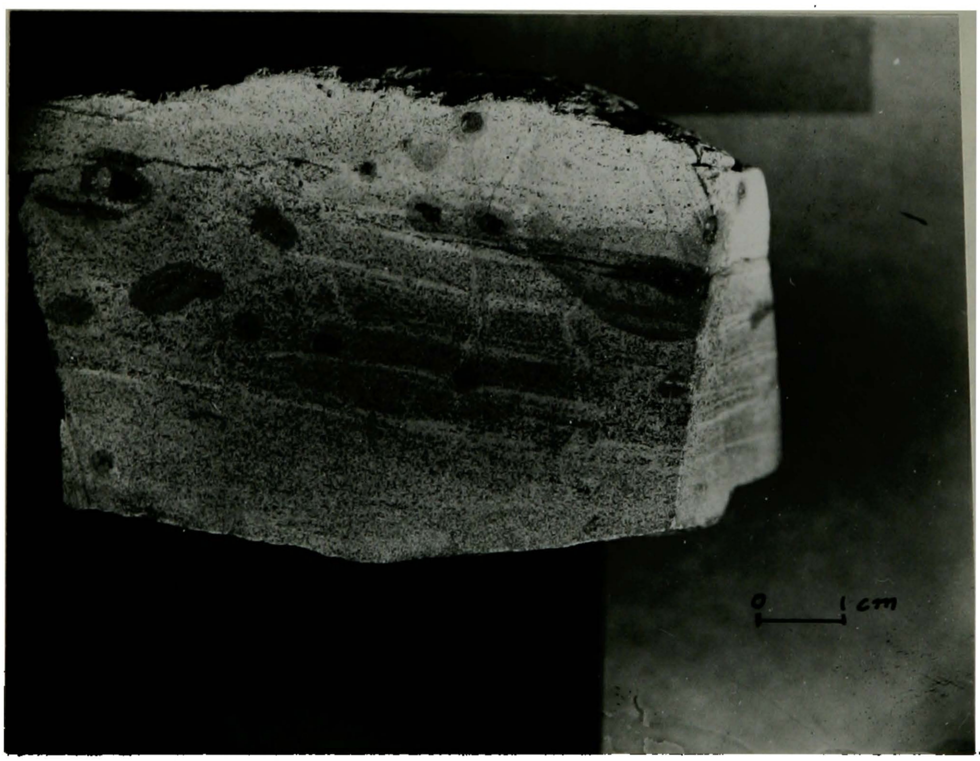


Figure 8. Upper Prichard calcareous argillite from along Lost Prairie road. It shows banding, black blebs of biotite porphyroblasts and pyrite with oxidation aureoles.

sections of Prichard argillite, stratigraphically lower than the calcareous unit, showed that about 50 percent of these rocks is composed of sericite in a micaceous mat formed by shreds about 0.004 millimeter in length. Sericite tends to lie parallel to the bedding. Quartz is present in amounts up to 40 percent, mostly as interlocking recrystallized grains in the sandy bands. Quartz ranges from 0.04 millimeter to 0.20 millimeter in diameter. Some larger grains, up to 0.35 millimeter in diameter, may indicate poor original sorting. Biotite is present in anhedral and subhedral poikilitic plates in amounts up to 10 percent. Textural relationships such as inclusions of quartz and zircons, and the non-preferred orientation suggest that it is metamorphic in origin. The weak pleochroism of the biotite prompted the writer to take x-ray measurements to determine the amount of iron it contained. The intensity ratio of the basal reflections (004) to (005) is known to increase as the amount of iron in the biotite increases. Using techniques employed by Gower (1957, p. 142) 53 percent of the octahedral positions of the biotite was found to be occupied by iron. The FeO content is about 25 percent. According to Foster's (1960, p. 25) triangular composition diagram, the biotite is magnesium rich. The low pleochroism is a reflection of this composition. Peninite, a variety of chlorite, is present in amounts of one percent as randomly oriented poikilitic crystals up to 1.5 millimeters in length. The poikilitic texture and the much larger size of the peninite compared to the size of the matrix in the rock suggests that peninite is metamorphic. Other constituents in these rocks are ilmenite and leucoxene present in amounts of about one percent and hematite, zircon, tourmaline and apatite, totaling less than one percent.

The leucoxene and hematite were observed to be spatially associated with the ilmenite, which suggests that this relationship resulted from the metamorphic alteration of ilmenite. Dark banding is produced by sericite bands and an increase in concentration of opaque minerals.

A thin section of the calcareous unit showed that about 40 percent of the rock consists of a mosaic of carbonate grains that range in size from a few hundredths of a millimeter to about one millimeter in diameter. The larger grains are most likely the result of recrystallization which these rocks have undergone. Small veinlets about 0.20 millimeter in thickness are present in the rock and filled with carbonate grains. This carbonate could have been hydrothermally introduced or may have been mobilized from the groundmass and introduced into these fractures during metamorphism. Quartz, commonly present in recrystallized clear grains and presenting chiefly a straight extinction, forms about 40 percent of the rock; it is unimodal and commonly ranges in diameter from 0.04 millimeter to 0.30 millimeter. Biotite porphyroblasts are present in anhedral and subhedral plates about 0.25 millimeter in diameter and in amounts up to 10 percent. They have a poikilitic texture with numerous inclusions of opaque minerals, quartz and detrital zircon. The biotite is oriented either perpendicular or inclined to the bedding. These distinctive features indicate that the biotite is metamorphic in origin. Sericite is present in shreds a few hundredths of a millimeter in length with no apparent preferred orientation and in amounts of about 8 percent. Pyrite, some of which is fractured, is present in small poikilitic anhedral blebs in amounts less than one percent and surrounded by limonite (Figure 8). Other minor constituents include apatite, zircon and tourmaline, which occur in small prismatic crystals up to 0.1 millimeter in length.

Correlation. Prichard rocks in the mapped area are correlated (Table 2) with lithologically and stratigraphically similar rocks in the Coeur d'Alene area, which were first described by Ransome (1905) near Prichard Creek. In the type section the rocks consist mainly of a gray-blue argillite and subordinate amounts of gray sandstones having a minimum total thickness of 8,000 feet (Calkins and MacDonald, 1909). On the basis of this description these rocks appear to be somewhat more sandy than rocks designated Prichard in the mapped area, although the last named represent only the upper 4,500 feet of the section. In the Libby Quadrangle, Prichard rocks are lithologically very similar to those in the mapped area. Here Gibson (1948) reports that Prichard Formation consists mostly of dark gray to blue-gray argillites interbedded with light colored sandstone and quartzite and having a minimum thickness of 9,700 feet; the base is not exposed. The argillites also weather to the red-brown color typical of the mapped area.

In Glacier National Park, where the Prichard Formation has not been recognized, the lowest exposed unit is the Altyn limestone, which consists of a dark, impure magnesian limestone that weathers to a grayish-orange. This unit contains stromatolite zones, is about 2,000 feet thick, and the base is not exposed (Ross, 1959b, p. 19). According to Ross (1959b, p. 18) the stratigraphic relationships between the Altyn and overlying clastic Ravalli Group rocks and the Altyn and Prichard Formation are not known. Ross (1959a, p. 59) has suggested that the Altyn may prove to be older than any of the units referred to as the Ravalli

	Coeur d' Alene Area Calkins & MacDonald (1909)	Libby Quadrangle Gibson (1948)	This Paper	Glacier Park Fenton and Fenton (1937)	Purcell Range British Columbia Schofield (1914)
Missoula Group	Top eroded Striped Peak	Top eroded Libby 6,000 Ft. Striped Peak 2,000 Ft.	Top eroded	Undifferentiated 4,800 Ft. Miller Peak ± 2,150 Ft.	Top eroded Gateway 2,000 Ft.
Piegan Group	Wallace 4,000-6,000 Ft.	Wallace 12,000 Ft.	Piegan Group ± 1,500 Ft.	Sheppard 585-1,500 Ft. Spokane 180-800 Ft. Siyeh ± 4,013 Ft.	Purcell Lava 300 Ft. Siyeh 4,000 Ft.
Ravalli Group	St. Regis Revett Burke (4,200 Ft.)	Ravalli Group 10,000 Ft.	Ravalli Group ± 10,000 Ft.	Grinnell ± 3,000 Appekunny ± 2,900 Ft. Altyn ± 2,260 Ft.	Kitchener 4,500 Ft. Creston 5,000 Ft.
Pre-Ravalli	Prichard 8,000 Ft.	Prichard + 9,000 Ft. (base not exposed)	Prichard ± 4,000 Ft. (base not exposed)		Aldridge ± 8,000 Ft.

Table 2. Belt Series nomenclature in northwestern Montana and adjacent areas

Group in Montana. In the Galton Series Daly (1912) recognized the Altyn limestone as stratigraphically equivalent to rocks below the Ravalli Group. Calcareous beds in the upper Prichard were recognized by Johns (1960, p. 8) east of the Kootenai River near the boundary of the Ural and Thompson Lakes Quadrangles. Shelden (1961, p. 32) also found minor calcareous interbeds at the top of the Prichard in the northwest Ural Quadrangle which he interpreted as possibly a more clastic equivalent of the Altyn. The writer recognized beds of calcareous argillite at the top of the Prichard Formation, but their relation to the Altyn is not known because the information available is very spotty and vague. It is noteworthy that the areal extent in which these calcareous beds are recognized is now enlarged with the present report.

RAVALLI GROUP

The Prichard-Ravalli contact is conformable and gradational through a zone 700 to 800 feet thick. It was placed between predominantly dark to medium gray argillites and predominantly light gray and grayish-green quartzitic argillite and argillaceous quartzite. Locally, poorly developed ripple marks were noted in this interval. It is noteworthy that calcareous beds occuring just below the Prichard-Ravalli contact provide a good marker horizon throughout most of the mapped area.

Rocks of the Ravalli Group are dominantly quartzitic argillites that range from medium gray to white in color. These rocks show well developed mud cracks and ripple marks. The more sandy members show good cross-bedding. Typically, Ravalli rocks weather in joint-bound blocks and form massive ledges, dip slopes and prominent talus slopes; when flat lying they may give rise to precipitous cliffs. Occasional beds that are ferruginous exhibit reddish or purplish tints on weathered surfaces. Ravalli rocks extensively underlie the mapped area.

The Ravalli Group is about 10,000 feet thick in the area of investigation compared with 9,500 to 10,000 feet in the Libby Quadrangle (Gibson, 1948) (Table 2). Immediately west of the mapped area, in the Thompson Lakes Quadrangle, the thickness of the Ravalli Group is more variable and ranges between 7,070 and 15,000 feet (Johns, 1960).

During most of the field season no attempt was made to map subdivisions of the Ravalli Group. However, toward the end of the field work it became apparent that three lithologic units could be distinguished, and might be mappable as subdivisions in future work. The lower unit is about 2,000 feet thick and consists mainly of a greenish-gray and gray-green argillite and argillaceous quartzites in beds that range from less than one foot to about 2 feet thick. These rocks weather to a pale green-colored surface. Abundant biotite, sparse magnetite and well developed mud cracks are characteristic of this basal unit. Rocks in the core of McGregor Lake anticline, north of the lake, were assigned to the lower Ravalli although they are not typical because they are more arenaceous, lighter in color and weather to a brown surface. These rocks consist of medium-light gray to light gray argillaceous quartzite and quartzite with well developed ripple marks (Figure 9). Minor interbeds consist of grayish-green argillite typical of the lower Ravalli. The rocks in this area do not appear to belong to the middle Ravalli unit because of their lighter color, brown weathering and more arenaceous character. Typical middle Ravalli rocks were observed higher in the stratigraphic section, east of the anticlinal axis in the southeast

Figure 9. Ripple marks in argillaceous quartzite of the lower Ravalli on Lost Prairie road, north of McGregor Lake.

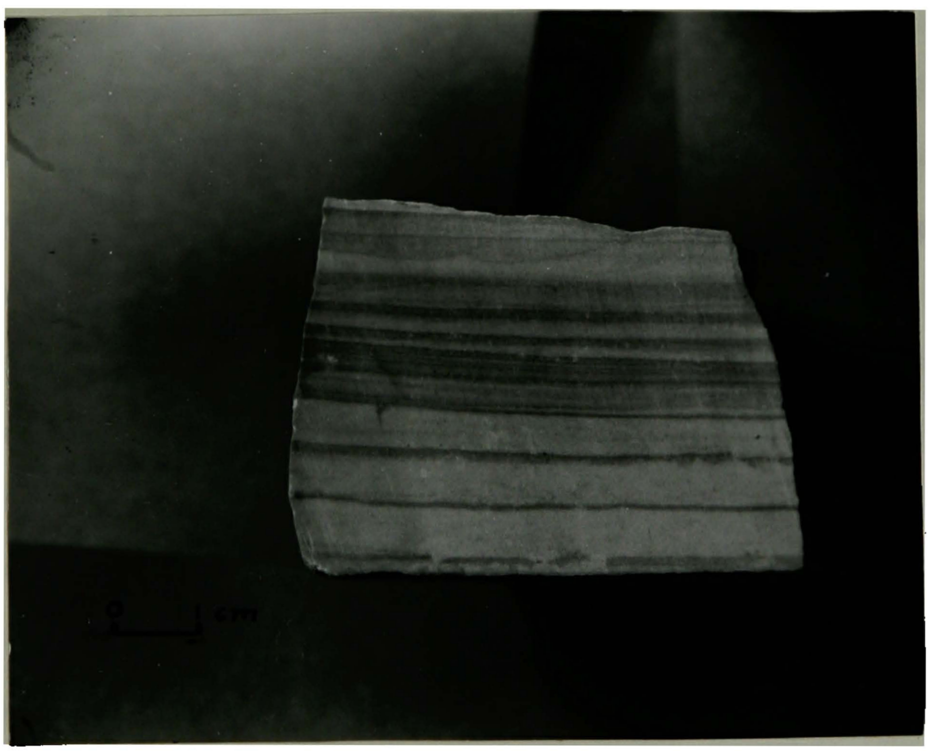


Figure 10. Evenly bedded purple-banded quartzite from upper Ravalli Group. Dark bands contain hematite and detrital opaque minerals.

quarter of section 32, T 27 N, R 25 W. The writer concludes that the rocks in question probably represent a facies change in the lower unit.

The middle unit is about 4,500 feet thick. It consists mainly of a light to medium gray quartzitic argillite and argillaceous quartzite in beds from less than one foot to about 3 feet thick. These rocks commonly contain magnetite octahedrons and locally, coarse biotite. Well developed mud cracks are abundant. The quartzites are usually faintly banded.

The upper unit is about 3,500 feet thick and consists mainly of a light gray to white quartzite. These rocks commonly exhibit distinct narrow purple bands, very well developed cross-bedding and ripple marks (Figure 10).

Petrography. Seven thin sections from Ravalli Group rocks were observed under the petrographic microscope. Five sections of argillaceous quartzites from the lower unit show that these rocks are composed of 45 to 55 percent partially recrystallized, subangular quartz grains. The quartz grains range in size from 0.04 millimeter up to 0.30 millimeter in diameter. They are clear with mostly straight extinctions. Subangularity is probably due to the deposition of silica around the grains, which produces grain enlargement and change in outlines. Sericite is irregularly scattered through this unit and forms 20 to 40 percent of the rock. Porphyroblasts of biotite, about 0.20 millimeter in diameter, were observed in amounts up to 10 percent. The biotite is poikilitic, enclosing crystals of quartz, zircon and opaques. Magnetite, the most important of the opaque minerals, is present in amounts of about one percent. It varies in size from a few hundredths of a millimeter to about 2.8 millimeters in diameter. The magnetite is porphyroblastic, and inclusions of quartz are common. Leucoxene forms about one percent of the rock. Metamorphic grains of plagioclase feldspar are present in amounts less than one percent. Other minor constituents are muscovite, epidote, hematite, illmenite and detrital apatite, zircon, tourmaline and rutile. In one section veinlets about 0.40 millimeter wide were observed filled with quartz and hematite, which may have been hydrothermally introduced or remobilized from the matrix during recrystallization. Sparse sulphides were observed in hand specimens but not in the sections examined.

One thin section of argillaceous quartzite from the middle unit of the Ravalli showed that this rock is composed of 70 percent interlocking quartz grains which range in size from 0.04 up to 0.40 millimeter with a median of about 0.10 millimeter. Most of the grains are clear with chiefly straight extinction. Poikilitic biotite porphyroblasts, from 0.10 to 0.35 millimeter in diameter, are randomly oriented and occur in amounts of about 10 percent. Sericite occurs randomly oriented and forms about 15 percent of the rock. Minor constitutents are ilmenite, leucoxene, hematite, muscovite, detrital rutile and tourmaline.

From a section obtained from the purple banded quartzites of the upper unit it was seen that these rocks contain about 90 percent recrystallized quartz grains with a median size of 0.15 millimeter. The quartz showed both undulose and straight extinction. Metamorphic plagioclase fledspar, which makes up about one percent of the rock, appears fresh and in sizes that range from 0.04 to 0.10 millimeter in diameter. Leucoxene forms about 2 percent of the rock. Other minor constituents are illmenite, hematite, muscovite, zircon and tourmaline, all totaling about 5 percent. Dark banding in these rocks is produced by an increase in the amount of opaques.

Correlations. F. C. Calkins (1909) applied the term "Ravalli Group" to rock assemblages above the Prichard Formation and below the Wallace Formation in northern Idaho and northwestern Montana. In the Coeur d'Alene region the Ravalli Group is divided into basal siliceous shales and sericitic quartzites known as the Burke Formation, a hard white quartzite and purple-green siliceous shales known as the Revett Formation, and a quartzitic sandstone called the St. Regis Formation. These three formations are assigned a total thickness of 4,200 feet (Calkins, 1909, p. 37 and Table 2). They are roughly equivalent to the three units described in the mapped area. In the Libby Quadrangle the Ravalli Group is undivided (Gibson, 1948) and consists primarily of dark gray argillite and light gray to white quartzite with abundant sedimentary structures. The Ravalli Group in that locality is estimated to be about 10,000 feet thick. Similar lithology is recognized in the mapped area with a comparable thickness. In the Thompson Lakes Quadrangle Johns (1960, p. 8) reports that the Ravalli Group, which varies in thickness from 7,070 to 15,000 feet, is dominantly quartzitic and comprises quartzite and argillaceous quartzite containing biotite and magnetite octahedrons. The rocks in the mapped area are broadly similar, although they do not present the wide variations in thicknesses reported by Johns.

In Glacier National Park the sequence later known as the Ravalli Group was divided by B. Willis (1902, p. 316) into the Altyn Limestone at the base, the Appekunny Argillite, and the Grinnell Argillite at the top (Table 2). Ross (1959a, p. 6) placed these formations in the Ravalli Group but assigned the Altyn to the Ravalli only provisionally. The Appekunny Argillite consists of interbedded argillites and quartzites in various shades of gray, green, purple and brown, and is about 2,900 feet thick. The Grinnell Argillite is about 3,000 feet thick and includes white and pink quartzite with interbedded, dominantly red argillite. Although these formations are termed argillites, according to descriptions by Ross (1959b, p. 21-34) their lithology is highly quartzitic. They also show an abundance of sedimentary structures common in stratigraphically equivalent rocks in the mapped area. There is only a gross lithologic resemblance of these Glacier Park formations to Ravalli rocks in the mapped area. Although the Appekunny Argillite may thicken to the west at the expense of the Grinnell Argillite, there is not sufficient field information to support this.

PIEGAN GROUP

The contact between the Ravalli Group and the overlying Piegan Group rocks is gradational through a zone about 300 feet thick. It was placed where commonly calcareous gray argillites of the Piegan overlie white and purple-banded quartzites of the Ravalli Group. The contact zone is well exposed on the crest of Meadow Peak.

Piegan rocks include the succession of strata above the Ravalli Group in which carbonates are characteristic. Piegan rocks crop out in the southwestern corner of the mapped area where only the basal 1,500 feet are exposed because erosion has removed the higher strata. Commonly the rocks show dark bands that range from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick. Mud cracks are abundant and very well developed (Figure 11), but ripple marks are

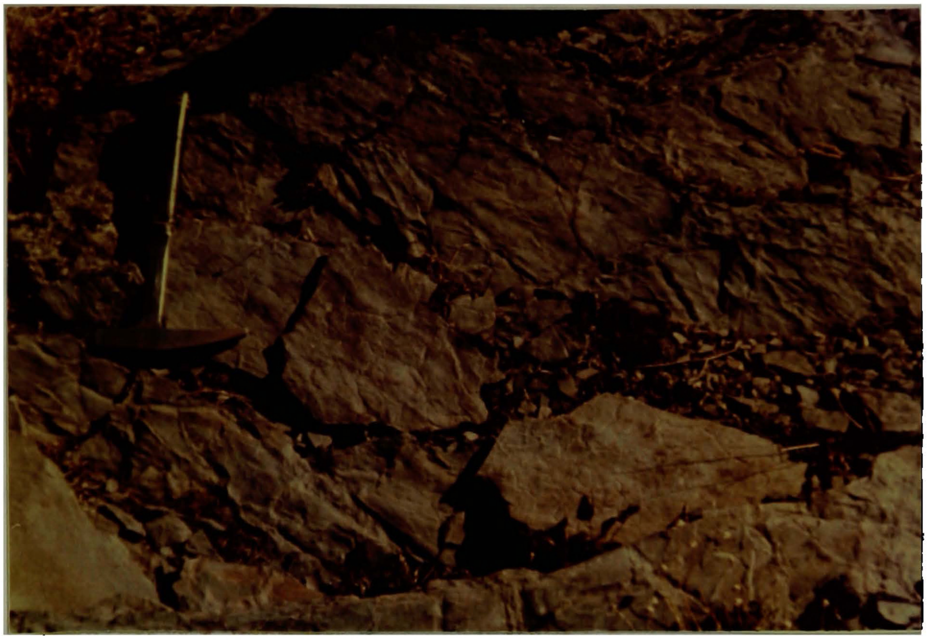


Figure 11. Thin bedded, mud cracked quartzitic argillite from basal Piegan Group.

sparse. The bedding ranges from less than one inch to about one foot thick in the more limy beds. In the mapped area about half of the specimens of Piegan tested were calcareous. Some horizons have orange-brown weathered surfaces produced by the weathering of sparsely disseminated pyrite.

Petrography. Two thin sections were made from Piegan rocks. A section of quartzitic argillite was seen to consist of about 60 percent sericite shreds only a few hundredths of a millimeter in length. Quartz, in grains that range from 0.01 to 0.30 millimeter in diameter with a median of about 0.10 millimeter, is present in the amount of 35 percent. The grains are clear and have mostly straight extinction. Other minor constituents are leucoxene and zircon, totaling about 5 percent.

A section of calcareous argillite contains about 40 percent quartz. The grains range from 0.01 millimeter up to 0.40 millimeter in diameter with a median of about 0.15 millimeter. The grains are clear with chiefly straight extinction. Calcite is present in grains from 0.06 to 0.40 millimeter in diameter and as cement between the quartz grains. The total amount of calcite present is about 40 percent. Sericite occurs in shreds up to 0.10 millimeter in length in the amount of 15 percent. Minor constituents are chlorite, ilmenite, leucoxene, zircon and muscovite, all totaling 5 percent. Dark banding is apparently caused by an increase in the amount of sericite and opaques.

Correlation. The Piegan strata of this study may be correlated with lithologically and stratigraphically similar rocks in the Ural Quadrangle, the Whitefish Range and Glacier National Park. In the Ural Quadrangle, Johns (1961, p. 15) has tentatively recognized three units in the Piegan Group. The lower unit is a thin-bedded or medium-bedded gray-green and medium gray argillite and quartzitic argillite. Approximately 50 percent of the rocks tested are slightly calcareous. No thickness is given for this unit but the descriptions correspond with stratigraphically equivalent rocks in the southwestern edge of the mapped area.

Descriptions of the lower Siyeh of Daly's Galton Series (1912, p. 104-106) closely resemble descriptions of stratigraphically similar rocks in the mapped area. They consist of medium to thin-bedded green and greenish-gray highly siliceous, sometimes dolomitic, argillite. Abundant sun cracks and ripple marks are present at various horizons. These rocks attain a thickness of about 800 feet. The difference in thickness from that in the mapped area may be explained by a thickening of the Piegan Group towards the south and west. In the northwest Ural Quadrangle, Shelden (1961, p. 19) reports that the Piegan Group is about

7,600 feet thick, of which the lower unit comprises 2,000 feet. His lower unit is considerably thicker than the 800 feet assigned by Daly to a similar sequence of rocks in the Whitefish Range.

In Glacier National Park, Fenton and Fenton (1937, p. 1893) described lower Piegan rocks as the Collenia symmetrica zone. These rocks are described as consisting of a medium- to thin-bedded quartzite, argillite and dolomitic argillite weathering green, brownish or buff with a thickness of 500 to 900 feet. These rocks have only a gross resemblance to rocks in the mapped area. Differences in thickness, lithology and the absence of the fossil algae Collenia symmetrica in the mapped area may be explained by a thinning of the rock unit towards the east accompanied by a change in the depositional environment. According to Fenton and Fenton (1937, p. 1893) their Collenia symmetrica zone may be correlated with the lower unit of Daly's Siyeh in the Galton Series.

QUATERNARY SEDIMENTS

Unconsolidated sediments recognized in the area are Pleistocene glacial deposits and stream gravels. During the reconnaissance field mapping, no attempt was made to map subdivisions of the Quaternary sediments and all were included under Quaternary Gravels. The glacial deposits (see p. 9-15) are of two types; stratified lacustrine silts and clays, and heterogenous till. Lacustrine deposits are exposed west of McGregor Lake in a road cut of U. S. Highway 2. These deposits are characterized by buff-colored, horizontally stratified, interbedded laminae of calcareous silt and silty clay. The till floors the valleys and dams the lakes found in the area. It was mapped as Quaternary Gravels where it exceeds an estimated 20 to 30 feet in thickness. In the larger valleys most of the streams have flood plains floored by thin and narrow alluvium.

CHEMICAL COMPOSITIONS AND METAMORPHISM OF BELT SERIES ROCKS

The chemical composition of seven samples taken from the Belt Series within the mapped area are shown in Table 3. The rocks include calcareous argillite, dolomitic argillite, siliceous argillite and quartzite. All of the rocks are moderately high in silica. Since CO_2 analysis were not available, it is assumed that in the calcareous rocks Mg and Ca are chiefly in the form of carbonates.

Inspection of the chemical analyses of the Belt rocks indicates that Prichard sediments, on the average, have 2.31 percent more of ferrous iron than the rest of the Belt rocks analyzed. This is explained by the widespread presence of pyrite in the Prichard compared to its absence or only sparse distribution in the rest of the Belt rocks. Further indirect evidence of probable higher pyrite content in Prichard sediments than in the other Belt rocks is the typical red-brown weathering produced by the oxidation of the sulphide at the outcrop.

Although the Prichard argillites observed under the microscope were high in quartz, the chemical composition of Sample A approaches the percentage of silica and aluminum oxide of muscovite (SiO_2-51.84 percent, Al_2O_3-25.81 percent, Brown, 1961, p. 231), which indicates that there are some very clean argillites present in the Prichard Formation.

The Belt rocks in the mapped area have undergone low grade regional metamorphism. It is very difficult to place a boundary between diagenesis and low grade metamorphism; according to Moorhouse (1959, p. 353)

TABLE 3

ANALYSES OF ROCKS OF THE BELT SERIES

(All analyses made in the laboratory of the Montana Bureau of Mines)

	A	B	C	D	E	F	G
SiO_2	60.0	59.2	73.8	71.6	81.0	66.2	59.3
Al_2O_3	23.25	17.2	14.7			18.9	16.65
Fe_2O_3	1.35	.56	1.40	1.74	.90	1.55	.43
FeO	4.04	3.84	1.28	1.80	1.28	1.28	2.80
MgO	2.38	2.7	1.45			3.1	6.5
CaO	1.1	6.7	1.0			1.5	4.2

(The samples at the left represent the stratigraphically lowest position)

A - Red-brown weathering Prichard Formation argillite. NW $\frac{1}{4}$ of Sec. 31, T 29 N, R 26 W
B - Calcareous argillite, top of Prichard Formation. SE $\frac{1}{4}$ of Sec. 25, T 28 N, R 27 W
C - Basal green Ravalli quartzitic argillite. NW $\frac{1}{4}$ of Sec. 23, T 27 N, R 25 W
D - Middle Ravalli unit quartzitic argillite. SE $\frac{1}{4}$ of Sec. 21, T 27 N, R 25 W
E - Upper Ravalli unit purple banded quartzite. SW $\frac{1}{4}$ of Sec. 20, T 27 N, R 26 W
F - Basal Piegan purple argillite. SE $\frac{1}{4}$ of Sec. 8, T 26 N, R 26 W
G - Basal Piegan calcareous (dolomitic?) argillite. SW $\frac{1}{4}$ of Sec. 8, T 26 N, R 26 W

diagenetic processes, such as the recrystallization of clays to chlorite, are common. Higher temperature and pressure developed by increased depth of burial resulted in the recrystallization of quartz and the formation of minerals, such as albite, muscovite and biotite, not originally present in the sediments.

The Belt rocks now display mineralogical assemblages that are indicative of the greenschist facies. Prichard argillites consist mainly of quartz, sericite, biotite and chlorite. The two lower units of the Ravalli Group rocks contain quartz, plagioclase, chlorite, biotite, muscovite and epidote. These two mineralogical assemblages are characteristic of the quartz-albite-epidote-biotite subfacies of the greenschist facies as set forth by Turner and Verhoogen (1960). The upper unit of the Ravalli Group and the basal Piegan Group rocks in the mapped area have a mineralogical assemblage consisting of quartz, sericite, chlorite and muscovite. This mineralogy would place these rocks in the quartz-albite-chlorite-muscovite subfacies of the greenschist facies. Thus, these rocks are the product of a lower grade metamorphism than the Prichard and lower Ravalli rocks. Mineralogical comparisons between rocks in the mapped area and similar rocks in the Libby Quadrangle (Gibson, 1948) and Glacier National Park (Ross, 1959a) indicate a correspondence in the mineralogical components. This suggests that the degree of metamorphism of these rocks is approximately similar to that of the rocks in the mapped area.

According to Daly (1912, p. 172) Precambrian sediments along the 49th parallel were metamorphosed before folding and faulting took place. Assuming that recrystallization obliterated any previous strain in the quartz, the undulose extinction in the quartz grains and the fractures in pyrite observed in Belt rocks in the mapped area may have originated from strain induced by deformation after the rocks underwent metamorphism. If metamorphism was simultaneous over the Belt terrane, faults with unmetamorphosed gouge in the Coeur d'Alene area (Silverman, personal communication) would also indicate that deformation took place after metamorphism was completed.

STRUCTURE

STRUCTURAL SETTING AND AGE OF DEFORMATION

In his division of the Great Cordillera, Eardley (1951) places the area east of the Rocky Mountain Trench in the Eastern System and the area west of the Trench in the Central and Western Systems. The Eastern System comprises the Foothill Division characterized by imbricate west-dipping reverse faulting and, the Mountain Belt Division bound on the east by the Lewis Overthrust and on the west by the Rocky Mountain Trench.

The map area is located in the Central System which embraces the Selish, Purcell and Cabinet Mountains in northwestern Montana. The region is characterized by broad folds and faults that generally trend northwest. Gibson (1948) and Johns (1961) have described three groups of faults based upon general trends. The oldest faults strike northwest, the second group strikes northeast, and the the third group strikes east. Faults of the second and third groups displace the northwest faults; hence they are younger. The time relationship between the northeast and east-striking faults is not yet clearly understood.

The structure of the map area follows generally a northerly trend. Two broad anticlines and two open adjacent synclines are the principal structural elements. These structures trend north or slightly west of north. The axial planes are essentially vertical. Several longitudinal faults and a transverse fault were mapped.

It is not possible to accurately date the age of deformation from evidence within the quadrangle because of the absence of Paleozoic and Mesozoic formations. There is some evidence of deformation prior to the

1960, p. 33).

deposition of Cambrian sediments elsewhere in Montana. Maxwell (1959), when studying the Cambrian-Beltian contact southwest of Drummond, concluded that the Belt Series rocks were strongly tilted, warped and probably faulted prior to deposition of Cambrian rocks. An angular discordance of the Belt rocks beneath the Cambrian in the Philipsburg Quadrangle (Emmons and Calkins, 1913, p. 30) also points to a tilting and gentle warping of the Belt rocks before Cambrian time. In southwest British Columbia, Precambrian intrusives related to the Purcell lava took paths of least resistance, probably tension cracks produced by feeble diastrophism (Ross, 1959b, p. 75). A faulted block of Devonian(?) limestone in the northeast Ural Quadrangle suggests that folding and faulting is at least post-Devonian (Johns, 1961).

Most geologists agree that the principal folding and faulting in northwestern Montana is related to the Laramide Orogeny of late Mesozoic and early Tertiary time. However, additional movements along new or older faults may have occurred during uplift and rejuvenation of the Rocky Mountains in late Tertiary time, movements that may not have entirely ceased. Johns (1959) has observed displaced Pleistocene lake beds and glacial till deposits on benches and valleys in the south part of the Yaak River 30 minute Quadrangle. A recent fault cut across moraines of at least two Pleistocene glaciers at Red Rock Pass, towards Henry's Lake, Idaho (Alden, 1953, p. 189). Just west of Yellowstone National Park in 1959 two fault blocks east of the Madison Range and one west of the Madison Range dropped, reactivating ancient normal faults with fault scarps appearing coincident or closely parallel to these faults. Release of the strains resulted in a major earthquake (Witkind, 1960, p. 31).

FOLDS

Belt Series rocks have been deformed into broad, almost symmetrical folds. Two anticlines and two synclines were mapped in the area (Plate 1). The Wolf Creek anticline (Johns, 1960) in the northwest corner of the area is a broad structure that trends north-northwest and plunges about 5^o to the southeast. Its fold axis is cut by a concealed fault along the Pleasant River Valley. The structure enters the area northwest of Island Lake and extends in a southerly direction crossing Pleasant River Valley and into the Pleasant Valley, where it plunges under the gravels. It has been mapped continuously for about 21 miles, (8 miles in the mapped area and about 13 miles in the northeast 15 minute Thompson Lakes Quadrangle (Johns, 1960)). Prichard strata are exposed in the core of the fold.

The east flank of the Wolf Creek anticline is the common west flank of the north-trending, broad, south-plunging Wolf Creek syncline. The limbs dip gently, varying from 5^o to 15^o on both sides. The structure is not found south of the Pleasant Valley but is continuous northward crossing the north boundary of the mapped area and continuing into the northwest quarter of the Pleasant Valley Quadrangle. F. Hall (personal communication) reports the structure extends in a northwesterly direction and reaches the north boundary of the Pleasant Valley Quadrangle, thus being continuous for approximately 30 miles. Prichard and Ravalli sediments are exposed on the western limb of the syncline. Ravalli rocks are continuous on the east.

The east flank of the syncline is the common west flank of the north-trending McGregor Lake anticline. The structure is broad with gently sloping limbs and is almost symmetrical in the north and central parts of the map area, changing to a more asymmetrical structure in the south part, north of McGregor Lake. Dips vary from 10° to 30° on the west limb and 10° to 15° on the east flank. The structure has been mapped continuously for about 20 miles extending into the northwest quarter of the Pleasant Valley Quadrangle.

The east limb of the McGregor Lake anticline is the common west flank of a north-trending syncline. The structure which was continuously mapped for about 20 miles, is almost symmetrical. The limbs dip 5° to 10° west of the axis and 10° to 20° east of the axis. The structure extends north into the northwest quarter of the Pleasant Valley Quadrangle. Ravalli Group sediments are exposed throughout the structure.

The trend of the folds suggests that the compressive forces in the area acted mainly along east-west lines, with the easiest relief upward. The axis of mean strain would be nearly horizontal and would strike north.

Thinning or thickening of the beds was not observed in the field. Scarcity of continuous exposures hindered the observations to such a degree that it is impossible for the writer to make a definite statement, but the gentle folding in the area and competent lithology suggest that the folding is essentially concentric.

FAULTS

Several longitudinal, high-angle faults and a transverse fault were mapped. Because the actual fault surfaces were not exposed, recognition of these structures depended upon the separation of rock units, drag, and physiographic anomalies. Since most of the map units present in the map area are thick and quite homogenous, faults with several hundred feet or more of displacement may have gone unnoticed.

A longitudinal fault was mapped just north of McGregor Lake, paralleling Lost Prairie Road for a distance of 2.5 miles. Recognition was on the basis of an abrupt change in dip over a small distance and a lithologic change. A few poorly developed slickensides on float were also found. The fault trace apparently is not affected by relatively low topographic relief, suggesting a vertical or close to vertical dip for the fault surface. The projection in a structure section of the gradational contact between lower Ravalli and middle Ravalli rocks east of the fault suggests a minimum displacement of 900 feet. The west block dropped down relative to the east block placing middle Ravalli against lower Ravalli rocks.

Along the above fault trace a small fold remnant truncated below by a fault surface was observed in a cut of Lost Prairie Road; underlying beds belong to the zone of drag just east of the fault. The truncating surface, which dips about 41° to the west, belongs in the fault zone but is not necessarily the master fault. The fold suggests a compressional origin, probably the result of deformation of a block or horse trapped between shear planes in the fault zone. This feature may possibly be the result of previous thrust faulting at a time when compressional stresses were great. Later, relaxation of the compressive forces could have caused tension and normal faulting along this zone of weakness, producing steepened west dips just east of the fault zone.

A longitudinal fault was mapped for one and a half miles north of

Little McGregor Lake. The drag of the beds indicates that the west side has dropped relative to the east side of the fault. There is no lithologic change observable across the fault trace. The amount of displacement appears to be very small.

The longitudinal fault mapped east of Lost Prairie Valley was based on a lithologic change and beds dragged down in the immediate vicinity east of the fault trace. The structure is interpreted to be a high-angle fault, with the west side down relative to the east side of the fault. Middle Ravalli rocks have been dropped down against lower Ravalli Group rocks. A minimum stratigraphic throw of 1,000 feet is indicated by projecting the base of the Ravalli Group from just east of the quadrangle border and inferring the position of the top of the lower Ravalli unit using its average thickness of 2,000 feet. The structure was extended northeastward approximately three and a half miles along a linear trending furrow which would indicate a zone of weakness. Topography does not affect the fault trace, hence the dip of the fault surface is interpreted as vertical. The fault cuts the synclinal axis of the fold before dying out. However, no displacement of the axial trace is shown because of the almost symmetrical nature of the fold.

The concealed transverse fault mapped on the west side of Pleasant Valley is required by the displaced Prichard-Ravalli contact. Projection of available data onto a structure section (B-B', Plate 1) indicates an approximate vertical displacement of 2,500 feet across Pleasant Valley. Since the nose is not offset laterally the movement was primarily dip-slip, with the south block upthrown relative to the north block.

Two small probable faults immediately south of Dahl Lake were mapped on the basis of abrupt changes in the attitude of the Ravalli strata over a short distance, slickensided float, two linear furrows, and the presence of springs. The relative movements on these two faults were not interpreted because of the insufficient information available.

A normal fault with minor displacement mapped by Johns (1960) in the southeast Thompson Lakes Quadrangle was continued for one and a half miles along a linear furrow in the southwest corner of the mapped area. The trace occurs in an area of Quaternary gravels in Long Creek Valley; however, these sediments are only a thin veneer and do not conceal the furrow in the bedrock below.

The fault at the center of the north border of the area was mapped by F. Hall in the northwest Pleasant Valley Quadrangle (personal communication). The only evidence for this fault in the area of study is a northeast-trending furrow that extends for slightly over a mile. According to Hall, the structure is a high angle normal fault with the east block down-dropped relative to the east block.

The study of lineaments on aerial photographs indicated the probable presence of three additional faults, trending approximately north-south, shown by special symbols in the northeast quarter of the geologic map.

JOINTS

A few attitudes of continuous joints scattered throughout the area were recorded. These joints apparently form sets that strike mainly N 55° to 80° W and N 50° to 85° E. The joints vary from 75° to vertical in dip, but they are mostly vertical. These joints are interpreted as shear fractures developed by compressive forces related to the folding and faulting of the Belt rocks. These forces acted generally in an east-west direction. Areas of prominent east-west joints essentially perpendicular to fold axes were also noted. These joints may be tensional in origin and are probably related to the transverse dip-slip fault in the area.

ECONOMIC GEOLOGY

Neither mining operations nor commercial mineralization were found during the course of the field work. Several quartz veins parallel to the bedding were sampled and analyses made by the Montana Bureau of Mines. They showed only traces of gold and silver. It is noteworthy that mineralized quartz veins parallel to the bedding are common in the Libby Quadrangle (Gibson, 1948, p. 74). These "bed veins" are favored by prospectors for gold in that locality.

East of McGregor Lake the Montana Highway Department operates a gravel pit in unconsolidated till. The gravels are screened and crushed to be used later in road maintenance as road aggregate.

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APPENDIX

PETROGRAPHIC THIN SECTIONS

Thin Sec. Number		Location
	Prichard Formation	
84	Upper Prichard calcareous argillite	SE $\frac{1}{4}$ of sec. 12, T. 28 N., R. 27 W.
40	Prichard quartzitic argillite ± 1,300 feet below upper contact	North end of Lynch Lake, SE $\frac{1}{4}$ of sec. 11, T. 28 N., R. 27 W.
50	Prichard quartzitic argillite ± 4,000 feet below upper contact	NW $\frac{1}{4}$ of sec. 36, T. 29 N., R. 27 W.
	Ravalli Group	
146	Lower Ravalli argillaceous quartzite	NW $\frac{1}{4}$ of sec. 22, T. 28 N., R. 26 W.
115	Lower Ravalli gray-green quartzitic argillite	NW $\frac{1}{4}$ of sec. 23, T. 27 N., R. 25 W.
130	Lower Ravalli argillaceous quartzite	SW $\frac{1}{4}$ of sec. 31, T. 27 N., R. 25 W.
140	Lower Ravalli quartzitic argillite	SW $\frac{1}{4}$ of sec. 31, T. 28 N., R. 26 W.
154	Lower Ravalli pure quartzite bed about 4 inches thick	NW $\frac{1}{4}$ of sec. 11, T. 28 N., R. 26 W.
101	Middle Ravalli quartzitic argillite	SE $\frac{1}{4}$ of sec. 11, T. 26 N., R. 26 W.
102	Upper Ravalli purple banded quartzite	Road below Lookout Tower sec. 20, T. 27 N., R. 26 W.
	Piegan Group Rocks	
207	Lower Piegan greenish-gray argillite	On ridge, sec. 8, T. 26 N., R. 26 W.
205	Lower Piegan calcareous argillite	NE $\frac{1}{4}$ of sec. 17, T. 26 N., R. 26 W.