STATE OF MONTANA
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BUREAU OF MINES AND GEOLOGY
E. G. Koch, *Director*

BULLETIN 42

December, 1964

PROGRESS REPORT ON GEOLOGIC INVESTIGATIONS IN THE KOOTENAI–FLATHEAD AREA, NORTHWEST MONTANA

6. SOUTHEASTERN FLATHEAD COUNTY AND NORTHERN LAKE COUNTY

By

Willis M. Johns

This bulletin has been prepared by the Montana Bureau of Mines and Geology under a cooperative agreement with the Great Northern Railway Company and the Pacific Power & Light Company

MONTANA BUREAU of MINES AND GEOLOGY
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MONTANA SCHOOL OF MINES
Butte, Montana
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Room 203-B, Main Hall

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Butte, Montana

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PROGRESS REPORT ON GEOLOGIC INVESTIGATIONS IN THE KOOTENAI-FLATHEAD AREA, NORTHWEST MONTANA

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ABSTRACT

This publication summarizes general geology for parts of the Elmo, Flathead Lake, Swan Lake, and Silvertip quadrangles located in southeastern Flathead County and northern Lake County in northwest Montana. The map area amounts to 1,000 square miles and includes the southeastern part of the Salish Mountains, the northern part of the Mission and Swan Ranges, and the central part of the Flathead and Lewis and Clark Ranges.

Topography is mountainous, many peaks rising to altitudes of 7,000 to 8,000 feet. Swan Peak in the Swan Range attains an altitude of 9,255 feet. Rivers and streams flow into the Flathead River, an upper tributary of the Columbia River flowing westward to northern Idaho.

Flathead Glacier moved down the Rocky Mountain Trench to Polson where it deposited the Polson moraine. During its southward advance, an ice lobe moving northwestward deposited the Ronan moraine near Proctor and scoured the Dayton bench at an altitude of approximately 4,200 feet, between Bow Lake and Rollins.

Rocks in the area range in age from Belt Series (Precambrian) to Tertiary. Belt Series rocks include the Ravalli, Piegan, and Missoula Groups, amounting to a thickness of nearly thirty-thousand feet in parts of the map area.

Middle and Upper Cambrian rocks are divided into nine formations whose aggregate thickness is 1,700 to 2,000 feet. Devonian strata, assigned a late Devonian age, total about 1,000 feet. Mississippian rocks equivalent to the Madison Limestone are present as erosional remnants capping high peaks and ridges. Farther east, in the Saypo quadrangle, Sloss and Laird assign a Mississippian age to rocks having a thickness of 1,230 to 1,700 feet. Kootenai beds (Cretaceous) are the cap of the lower plate of the Lewis overthrust. Tertiary clastic rocks, which may be the equivalent of the Kishenehn Formation, present within the valley of the North Fork Flathead River, crop out as a remnant north of Spotted Bear.

Symmetrical folds, the major ones being the Silvertip syncline and the Ronan anticline, strike north and northwest throughout the area.

Large northwest-trending high-angle normal faults are mapped on the east side of the Rocky Mountain Trench, in Swan Valley (Swan fault), and in the valley of the South Fork. Two overthrusts, the Lewis thrust and a subsidiary thrust, strike north and northwest respectively and have large displacements. A set of minor faults strikes west-northwest.

Mineral production from the quadrangles, mainly between 1900 and 1930, has been insignificant. A fissure-filling barite deposit at the head of Black Bear Creek in unsurveyed T. 23 N., R. 13 W., is developed by two open pits.

I N T R O D U C T I O N

This bulletin is the sixth in a series of annual progress reports describing the results of reconnaissance mapping in four northwest counties in Montana. Previous reports are Montana Bureau of Mines and Geology Bulletins 12, 17, and 23 presenting geologic data from Lincoln County, Bulletin 29 describing work in southwestern Flathead County and a small part of northern Sanders County, and Bulletin 36 describing geology of western Flathead County. This final progress report summarizes the results of field work in southeastern Flathead County and northern Lake County (Fig. 1).

The Kootenai-Flathead program commenced in 1958 under the joint sponsorship of the Montana Bureau of Mines and Geology, Great Northern Railway Co., and Pacific Power & Light Co. Through the mapping program and the minerals-identification service in Kalispell, the sponsors hope to encourage prospecting and mineral development in northwest Montana. Additionally, a limited geochemical program for detecting vein structures by use of a mercury sensor in combination with soil sampling for standard metal-ion determination was tested in the Libby quadrangle; the results of the test program are discussed in this final progress report.

Areas mapped during the 1963 field season (Fig. 1) were the north Elmo quadrangle and Flathead Lake quadrangle within the southern part of the Salish Mountains, the northwest and east parts of the Swan Lake quadrangle in the northern part of the Mission and Swan Ranges, and additions were made to the Charles Deiss geologic map of the Silvertip quadrangle in the Flathead Mountains and Lewis and Clark Range.

Geologic observations were plotted on Forest Service planimetric maps and, where these were unavailable, on U. S. Forest Service maps in conjunction with U. S. Geological Survey 30-minute topographic sheets. Vertical aerial photographs were available for parts of the Elmo and Flathead Lake quadrangle map areas.

Field work was completed during the summer and fall of 1963 by W. M. Johns and W. D. Page during a 5-month period.

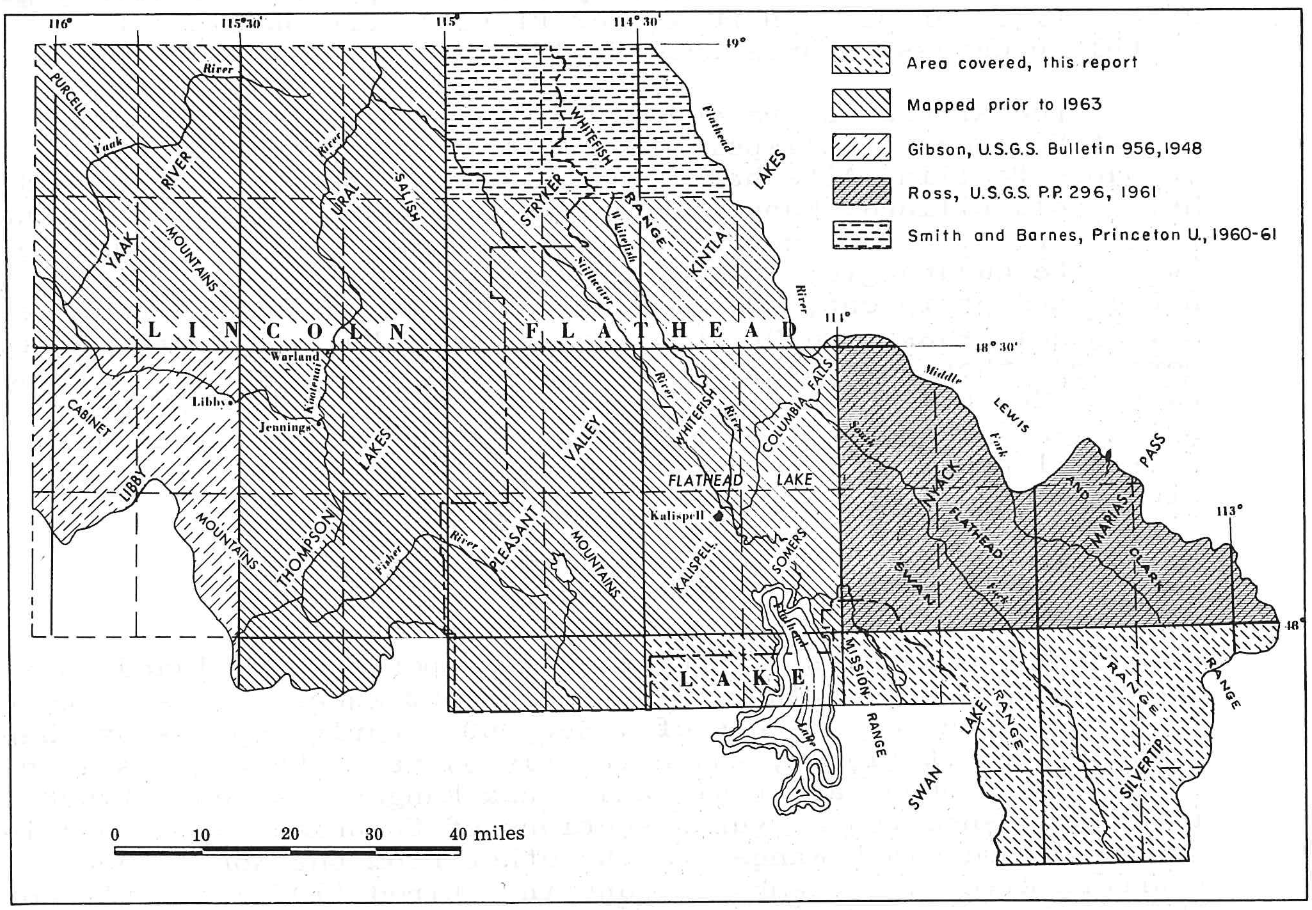

Figure 1.--Index map of northwest Montana showing location of quadrangles.

SCOPE OF REPORT

The map area (Pl. 1, 2, and 3) lying within southeastern Flathead County and northern Lake County embraces an area of 1,000 square miles. A major part of the Bob Marshall Wilderness Area lies within the Swan Lake and Silvertip quadrangles, and the Sun River Game Preserve abuts the eastern map boundary on the east slope of the Lewis and Clark Range.

ACKNOWLEDGMENTS

All project costs for the program during the fiscal year of 1963 were supplied by the Pacific Power & Light Co. and the Great Northern Railway Co. to the Kootenai-Flathead project fund.

The author wishes to thank Mr. U. M. Sahinen, Associate Director, Montana Bureau of Mines and Geology; Mr. G. A. Duell, Staff Geologist, Pacific Power & Light Co.; and Mr. R. A. Watson, Geologist, Great Northern Railway Co., for both program planning and editing the manuscript. Mr. W. D. Page, Geologist, U. S. Bureau of Reclamation, critically read the paper, and lithologic descriptions of Beltian rocks for Plate 2 were obtained from monthly progress reports submitted by him.

Special thanks are due to Mr. John Hall of the U. S. Forest Service at Kalispell, Mr. Dick Strong, Ranger, and Mr. Theodore Paullin, Alternate Ranger, Spotted Bear District; and Mr. Arnold Dillard, Ranger, Big Fork District, Flathead National Forest, for their cooperation and assistance while mapping the Swan Lake quadrangle; to Mr. Lee Rost of Perma who supplied horses and equipment; and to Mr. Fred Sproul of Star Meadows and Mr. Manuel Bauska and Mr. Guy Maycumber of Kalispell, for equipment and other assistance during the field season. Mr. Bill Adams, Dayton, Mr. Bill Creasy, Mr. Levi Gaustad, Mr. Ben Trosper, Mr. Homer Julian, Mr. Lawrence Staabs, and Mr. Al Harvey of Kalispell provided information concerning mines and prospects within the quadrangles.

PREVIOUS WORK

The quadrangles mapped for this report are included in a reconnaissance map (Clapp, 1932) of 16,000 square miles in northwestern Montana on a scale of 1:500,000. Early reports by Chapman (1900), Walcott (1906), and Bevan (1929) describe traverses in the Mission, Swan, and Lewis and Clark Ranges. Walcott (1908, 1917) published two measured sections of Cambrian rocks, one in the Lewis and Clark Range and the other from the North Fork Dearborn River to Steamboat Mountain. Elrod (1903) briefly noted the physiography of Flathead Lake, and Davis (1916, 1921) studied the effects of valley glaciers in the Swan Range and both the Flathead lobe and valley glaciers in the Mission Range. Kindle (1908) described the Jefferson Limestone in the northern Rocky

Mountain region and Burling (1914) reassigned the lowest Cambrian rocks to a Middle Cambrian age in Walcott's Dearborn River section. Papers by Deiss (1933, 1935, and 1938) are concerned with the Cambrian-Missoula Group unconformity and the stratigraphy of Paleozoic rocks in parts of the Swan Lake, Silvertip, and Ovando quadrangles. During 1947 Deiss assembled geologic data for the Silvertip quadrangle and subsequently made available to the Montana Bureau of Mines and Geology his unpublished map of this area, which is reproduced for this report. Sloss and Laird (1947) discussed Devonian stratigraphy in Montana including studies of Devonian rocks in the Flathead Mountains and Lewis and Clark Range. Alden (1953) described the physiography and glacial geology of Flathead Lake and adjacent areas, the Swan and South Fork Flathead Rivers, and sections of the Mission and Swan Ranges.

Geologic studies in peripheral areas were done by Willis (1902), C. L. and M. A. Fenton (1937) in Glacier National Park, and by Ross (1959) in the Nyack and Marias Pass quadrangles. Daly (1912) mapped a strip along the 49th parallel between the Rocky Mountain Trench and the Great Plains. Johns and others (1963) published a progress report describing geology in the south Whitefish Mountains, northeast Salish Mountains, Kalispell vicinity, and the Hog Heaven mining district. Mudge and others (1962) described Mississippian rocks in the Sun River Canyon of the Sawtooth Range, and Childers (1963) studied structure and stratigraphy southwest of Marias Pass in the Marias Pass quadrangle. Deiss (1943a, 1943b) was the earliest worker to report on detailed stratigraphy and structure in the Ovando and Saypo quadrangles, and based on this work and earlier work in adjacent areas, he assigned four map units to the Missoula Group, divided the Cambrian section into nine formations, reassigned Devonian rocks to Late Devonian age, and described three structural provinces in the central Sawtooth Range.

Erdmann (1944) contributed data concerned with glaciation and Belt Series stratigraphy during dam-site studies on the South Fork Flathead River. Cenozoic block faulting in Flathead, Swan, and South Fork Valleys was described by Pardee (1950). In a recent publication, Ross (1963) summarizes data on the Belt Series throughout Montana.

G E O G R A P H Y

LOCATION AND ACCESSIBILITY

The west portion of the map area is in parts of the Elmo and Flathead Lake quadrangles and includes Lake Mary Ronan and central Flathead Lake. The east portion lies east of Flathead Lake and south of Hungry Horse Reservoir in the Swan Lake and Silvertip quadrangles, and is traversed in a northerly direction by the Swan, South Fork Flathead, and Spotted Bear Rivers.

The quadrangles are bounded by latitude 48° on the north. The southern boundary from Lake Mary Ronan to Swan divide conforms to the 6th Standard Parallel north, latitude 47°52'26½". The boundary then swings south along Swan divide to pass south of Owl Peak, there to swing east along latitude 47°36'52" following the Missoula-Powell-Flathead County line to the Continental Divide. The west boundary is longitude 114°30'. The east map boundary follows the irregular crestline of the Continental Divide separating Flathead County from Lewis and Clark County.

The area west of the Swan divide is accessible to vehicles by numerous roads including federal and state highways and county and forest service roads. Terrain east of Swan divide and south of Spotted Bear is accessible only by trails. Within this region is part of the Bob Marshall Wilderness Area, established in 1940 as part of a system of wilderness and primitive areas under the jurisdiction of the U. S. Forest Service, where access is permitted only by hiking or horseback. It is advantageous to use pack animals to transport equipment and supplies for extended stays.

U. S. Highway 93 and State Highway 35 are north-south access routes following the west and east shores of Flathead Lake, respectively. State Highway 209 follows Swan Valley to Flathead Valley and Kalispell. At Martin City and at Hungry Horse, forest service roads leave U. S. Highway 2 southbound following the east and west shores of Hungry Horse Reservoir to Spotted Bear Ranger Station at the south terminus of the road.

A major route for entering the Wilderness Area is U. S. Forest Service Trail 80, which follows the South Fork Flathead River upstream from Spotted Bear to Big Salmon Lake and beyond. East of Spotted Bear, Trail 80 ascends the Spotted Bear River to Spotted Bear Pass on the Continental Divide, thence continuing down Rock Creek to the North Fork Sun River. Trail 101 ascends Bunker Creek to cross Swan divide to Swan Lake via Trail 21, descending Bond Creek. Other trails ascend Gorge, Cannon, and Trickle Creeks and Little Salmon Creek. A crossover trail between White River and the South Fork ascends Pagoda Creek passing Pagoda Mountain by way of Helen Creek to Blackbear Guard Station on the South Fork. From Shafer Meadows, Trail 155 enters the Silvertip quadrangle following Bowl Creek to Sun River Pass.

Flathead and Kootenai tribes of Salish-speaking Indians living west of the Continental Divide crossed the Flathead Mountains and the Lewis and Clark Range to the Great Plains on semi-annual buffalo hunts in prehistoric times. An ancient Indian trail locally known as the "Turtle Trail" is believed to have passed northeast of Lake Mary Ronan to Fatty Lake crossing the Mission divide, then along Fatty Creek to Swan Valley. Swan River was forded just south of Goat Creek, and the trail continued up Goat Creek to cross the Swan divide at Inspiration Pass. From the pass the trail is believed to have followed Bunker Creek to its junction with Gorge Creek. Eastward from this junction to the Great Plains the trail followed the north bank of Bunker Creek to the South Fork and continued downriver to Spotted Bear. It continued up Spotted Bear River, crossed Spotted Bear Pass to Rock Creek, and proceeded down the North Fork Sun River to the Plains. In recent years old Indian markings on trees* were still visible where the trail crossed the Mission Range.

TOPOGRAPHY AND DRAINAGE

Mountain ranges in the area are rugged linear uplands separated by subparallel river valleys within Fenneman's (1931) Northern Rocky Mountains. Physiographic history of the province commences with the Laramide Revolution (late Cretaceous through early Tertiary) when Precambrian, Paleozoic, and Mesozoic rocks were folded, faulted, and elevated many thousands of feet above sea level. During Oligocene and part of Miocene time the Late Tertiary Peneplain (Pardee, 1950) was formed, and western Montana was reduced to gentle slopes. Later uplift and erosion so modified it that now only remnants of the former extensive plain remain at mountain and ridge crests.

Several north-south-trending mountain ranges are within the map area (Fig. 2). From west to east they are the Salish Mountains, west of Flathead Lake; the Mission Range, separating Flathead Lake and Swan Valley; the Swan Range, in a median position between Swan Valley and the South Fork; the Flathead Mountains, between the South Fork and Middle Fork Flathead Rivers; and the Lewis and Clark Range lying east of the Middle Fork Flathead and White Rivers. An adjoining range east of the Lewis and Clark Range but outside the map area is the Sawtooth Range, fronting the Great Plains.

The Salish, Mission, Swan, and Flathead Ranges are officially recognized, but not the Lewis and Clark Range. This name was first used by Bevan (1929, p. 430, fig. 1) for that part of the Rocky Mountain front east of the Continental Divide between Glacier National Park and the Missouri River.

For this report the mountain masses in the map area between the Middle Fork Flathead and White Rivers and extending to an irregular boundary east of the Continental Divide will be regarded as within the Lewis and Clark Range.

The boundary between the Flathead and Lewis and Clark Ranges from Glacier National Park to Schafer Meadows (Fig. 2) is the Middle Fork Flathead River; the line then follows Dolly Varden Creek, crosses a divide between Pot and Pentagon Mountains, and continues down Pentagon Creek, up Wall Creek, and down White River to its junction with the South Fork. This terminates the Flathead Range within the U-shaped lower section of White River, as stated by Deiss (1933, p. 46), that the "White River separates the Flathead and Lewis and Clark Ranges". It is somewhat south,

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*Lee Rost, personal communication.

however, of where Pardee (1950, p. 398) placed the boundary (namely, its junction with the Continental Divide at the head of White River). This would place the entire length of the Continental Divide between Glacier National Park and Rogers Pass, an area referred to by the Blackfoot Indians as the backbone of the world, within the Lewis and Clark Range.

The Sawtooth Range, farther east, is described by Deiss (1943b, p. 1125-1129) as forming the front of the Rocky Mountains between the South Fork Two Medicine Creek and the North Fork Dearborn River. South of Two Medicine Creek the boundary between the Lewis and Clark and Sawtooth Ranges follows the South Fork of Badger Creek and skirts the upper eastern slope of the Continental Divide to the head of North Fork Sun River. South of this location the boundary as described by Deiss would be the north and south forks of the Sun River to Wood Canyon, thence continuing up Wood Canyon to the range front.

In the Elmo and Flathead quadrangles, in the west map area, a small portion of the Salish Mountains presents a mature topography of gradual slopes and moderately smooth summits. From the southwest corner of the map area a semicircular ridge pattern extending to Kerr Mountain at the east end rises to altitudes of 6,200 feet. From it east- and south-trending ridges descend to basins occupied by Lake Mary Ronan and Flathead Lake. Lake Mary Ronan has an altitude of 3,300 feet and Flathead Lake an altitude of 2,893 feet, hence maximum relief is 3,000 feet.

The area is drained by Dayton Creek, which flows into Flathead Lake, and Hilburn Creek, which flows to Lake Mary Ronan. This lake has a southern outlet and probably some underground drainage eastward to Dayton Creek through the moraine bordering its east shore.

Between Flathead Lake and Swan Lake is the Mission Range, a distinctive linear northward-trending topographic unit extending north to Bigfork and disappearing beneath gravels and silts in Flathead Valley. The range has been described by Davis (1916) and Erdmann (1944) as a tilted and moderately dissected block bounded by faults beneath Flathead and Swan Valleys.

Topographic expression of the Mission Range is a low flat-topped divide of moderate relief and bounded by gentle slopes. East of Yellow Bay the crest rises abruptly to 6,000 feet, maximum relief amounting to 3,000 feet. From Polson south, the crest-line continues to rise, attaining an altitude of 9,800 feet. The western front becomes more precipitous, contrasting to a broad east slope. Drainage is consequent, streams flowing perpendicular to range trend into Flathead Lake, Swan Lake, and Swan River. Swan River flows north to enter Flathead Lake at Bigfork.

The Swan Range forms the east border of Swan Valley, paralleling the Mission Range and extending northward beyond Badrock Canyon of the Flathead River. North of the canyon the range continues (Teakettle Mountain) $5\frac{1}{2}$ miles to terminate at the North Fork Flathead River.

The central part of the Swan Range (Pl. 2 and 3) is wider than the Mission Range and its terrain is more rugged. Its western slope presents a moderately steep front, contrasting to the broad east flank. The Swan divide between Sixmile Lookout

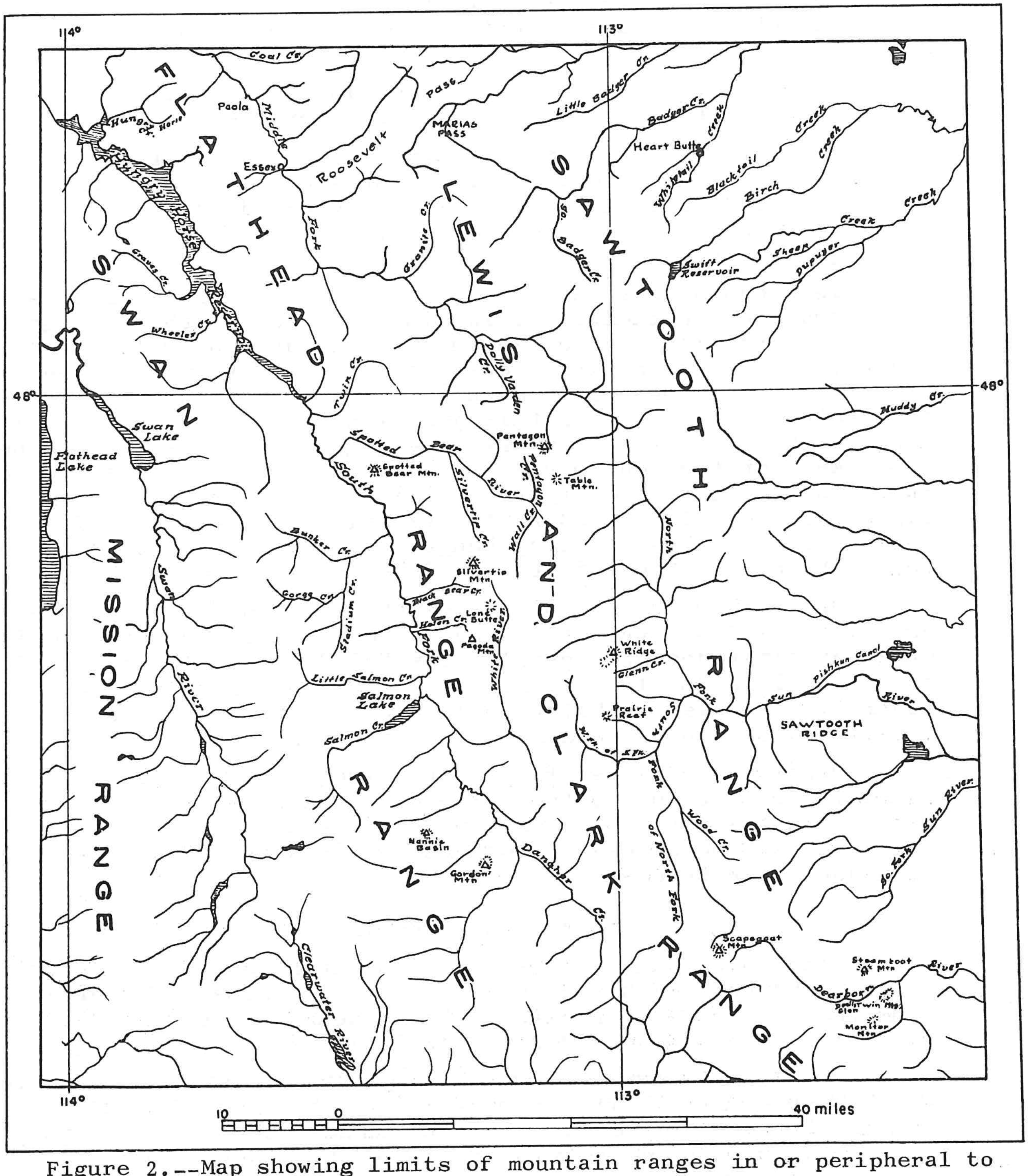

Figure 2.--Map showing limits of mountain ranges in or peripheral to quadrangles.

and Thunderbolt Mountain attains altitudes of 6,600 to 7,300 feet. From Thunderbolt Mountain (7,915 feet) south to Swan Peak (9,255 feet) the crestline has an average relief of 4,000 feet, maximum local relief amounting to 6,000 feet. Within the eastern slope, Garnet and Stadium Peaks rise to altitudes of 8,129 feet and 8,630 feet respectively. Altitudes for Alcove Mountain (7,800 feet), Picture Lookout (7,725 feet), Bruce Mountain (7,643 feet), and Bunker Peak (7,125 feet) are progressively lower. North of Bunker Creek are Soldier Mountain (6,349 feet) and Kah Mountain (6,390 feet).

The map area is drained by the Flathead River (and its tributaries), which flow into Clark Fork of the Columbia River.

On the west flank of the Swan Range, streams flow west to Swan Lake and Swan River. On the east slope, drainage is both consequent and subsequent through a maturely dissected backslope, both differential erosion and direction of slope controlling drainage patterns.

The mountainous terrain between the South Fork Flathead River and the Continental Divide includes the Flathead Range and Lewis and Clark Range, which are separated by Dolly Varden and Wall Creeks to a divide east of Silvertip Mountain, the boundary continuing thence down White River to its junction with the South Fork. South of this junction, the Flathead Mountains merge with the Lewis and Clark Range. These ranges occupy the slope west of the Continental Divide, and with the exception of Swan Peak, contain the highest summits in the mapped area: Silvertip Mountain (8,890 feet), Pentagon Mountain (8,877 feet), Table Mountain (8,380 feet), Bungalow Mountain (8,140 feet), and Pagoda Mountain (8,030 feet). Relief is 2,800 to 4,600 feet.

On the Continental Divide south of Larch Hill Pass, the crestline is a spectacular topographic feature named the "Chinese Wall" at altitudes of approximately 8,000 feet. The east side of the wall is an almost vertical 1,000-foot cliff continuing south for 9½ miles to Haystack Mountain. The west slope is a moderate dip slope extending to White River.

Drainage patterns (Pl. 3) are diverse, South Fork flowing slightly west of north, the White River flowing south, and Spotted Bear River flowing north and northwest. Generally, other tributary drainages have submature patterns and flow perpendicular to major river trends.

CLIMATE AND VEGETATION

Climatological records for temperature and precipitation compiled by the Weather Bureau of the U. S. Department of Commerce are listed for five stations nearest the map area. These data are summarized for 1962 in Table 1.

Annual mean temperatures during 1962 for stations in valleys at altitudes near 2,800 feet was 45°F. At higher altitudes (Hungry Horse Dam, Gibson Dam) mean annual temperature was 2° to 3° lower. Annual precipitation within the lower valleys averaged 14.5 inches, whereas precipitation at higher altitudes ranged

TABLE 1

Average temperatures in °F (1962).

Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.	Departure from normal
Bigfork	23.1	29.3	34.2	47.6	51.4	60.2	65.4	63.0	56.4	46.4	39.6	35.4	46.1	---
Gibson Dam	21.4	23.2	27.3	43.5	46.4	55.0	59.1	60.8	52.4	47.4	37.9	32.7	42.3	0.6
Hungry Horse Dam	18.6	24.1	30.8	44.5	49.1	58.2	64.4	63.3	54.4	44.1	37.2	32.0	43.4	---
Kalispell	17.8	25.7	31.2	46.7	52.0	59.0	64.0	62.6	54.6	44.2	37.1	32.3	44.0	---
Polson Airport	20.0	28.8	32.9	46.8	50.7	59.2	64.7	64.4	56.0	45.4	37.9	34.1	45.1	-0.4

Total precipitation in inches (1962).

Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.	Departure from normal
Bigfork	1.76	1.51	2.00	1.23	3.44	1.32	0.35	1.48	1.30	2.34	1.20	1.70	19.63	---
Gibson Dam	0.72	0.89	0.63	1.58	9.62	3.09	0.92	1.39	0.67	2.28	0.76	0.43	22.98	5.49
Hungry Horse Dam	1.53	1.75	2.98	3.06	3.39	0.95	0.29	2.04	2.15	5.00	4.74	2.40	30.28	---
Kalispell	0.89	0.77	1.01	0.74	2.22	1.07	0.21	0.57	0.75	1.51	1.21	0.92	11.87	---
Polson Airport	0.70	0.65	0.75	0.63	2.63	0.83	0.29	1.37	1.17	1.88	0.69	0.78	12.37	-2.66

from 23 to 30 inches. In 1960, precipitation amounted to 27.36 inches at Spotted Bear Ranger Station.

Average summer temperatures within the map area are moderate to mild. Most severe winter temperatures are usually recorded in January. Cumulative snowfall within the mountains may amount to 12 feet or more during winter months.

Areas are forested with several species of pine and fir, Western larch, Engelmann spruce, aspen, juniper, maple, alder, and several types of birch. Common shrubs are willow, huckleberry, service berry, currant, chokeberry, elderberry, and mountain ash. Within valleys and parks are many varieties of grass, such as Idaho fesque, bunchgrass, beargrass, jointgrass, wheatgrass, and needlegrass.

GLACIATION

During the Wisconsin stage of the Pleistocene epoch a glacier, named by Alden (1953, p. 115) the Flathead glacier, advanced from southern British Columbia across the 49th Parallel through the Rocky Mountain Trench to the vicinity of Polson (Fig. 3), where the Polson terminal moraine was deposited (Alden, 1953, p. 119).

As the Flathead glacier traversed Flathead Valley past the ice-filled Swan Valley beyond Bigfork, part of the glacier was forced to override the northern Mission Range to a point near Mission Wells by the constricting effect of the depression. Evidence for this overriding is found along parts of the northern Mission divide where the crestline has been beveled to a flat-topped or smoothly rounded surface covered by glacial drift. Along the divide south of Mission Wells the range abruptly rises to altitudes near 6,000 feet, and the exposed bedrock shows no ice scouring, thus indicating that the uppermost limit of the ice reached 5,000 feet above sea level along the Mission divide. From Mission Wells to Polson the ice margin cut diagonally downward and across the west side of the Mission Range to the valley floor.

West of Flathead Lake (northwest of Lakeside), ice reached a minimum altitude of 5,100 feet. At a small lake in the southwest corner of sec. 14, T. 27 N., R. $21\frac{1}{2}$ W., the position of a moraine indicates the upper ice limit and suggests southeastward movement toward Rollins (Johns and others, 1963, p. 11).

Ice movement continued through the valley now occupied by Flathead Lake, the west margin of the ice crossing drainages west of Angel Point and Table Bay. At Rollins the ice mass moved over a spur ridge toward Lake Mary Ronan.

Alden (1953, p. 119-122) describes subsidiary ice lobes extending up Big Draw, at Elmo, and west of Big Arm, where terminal moraine was deposited, thus fixing the southwest limit of Wisconsin ice. The main axial lobe continued down the Trench and deposited the Polson moraine in an irregular arcuate mass between Polson and the Mission Range.

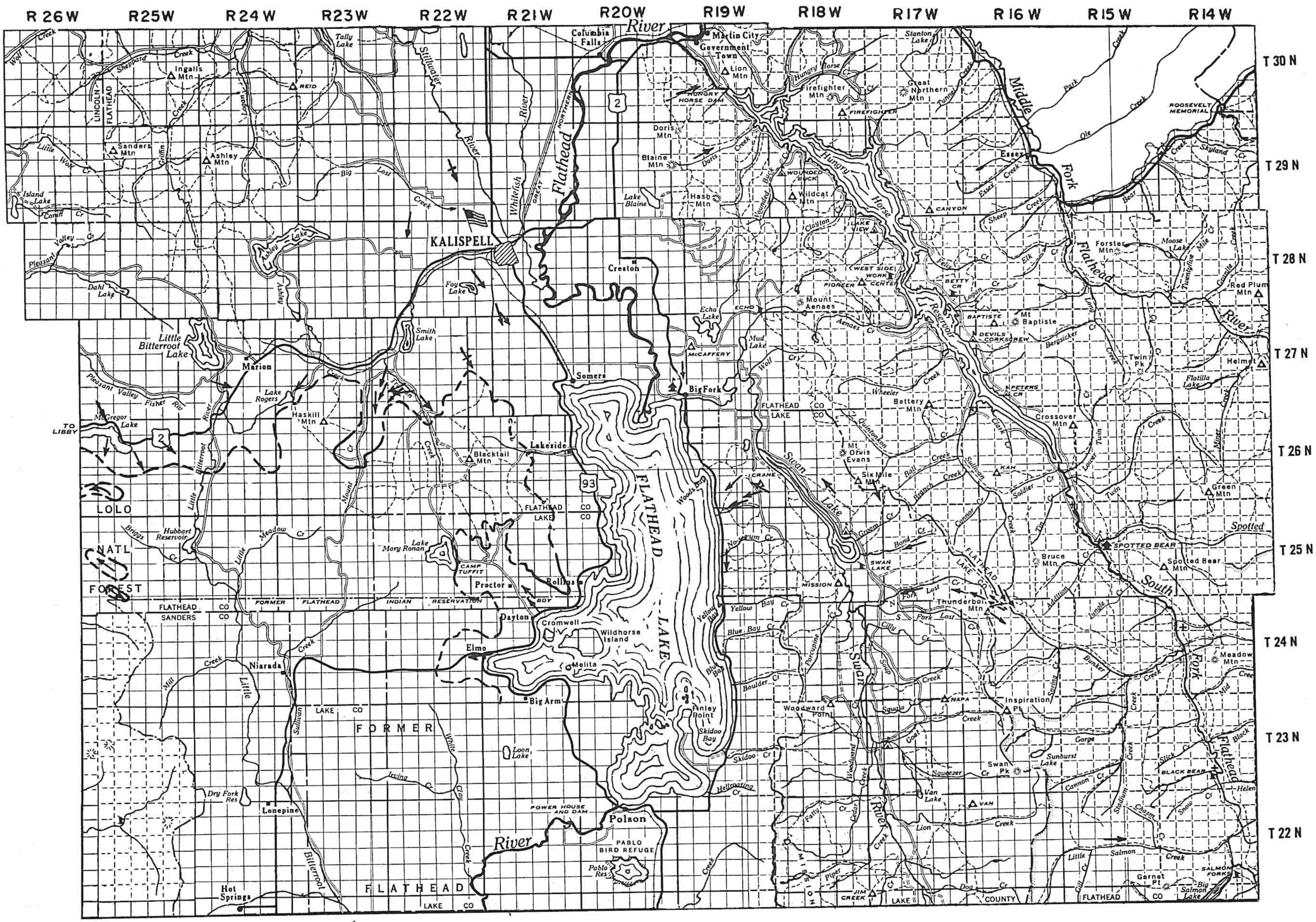

Figure 3.--Map showing movement of Flathead glacier and other valley glaciers.

Alden (1953, p. 122) states that well-marked shorelines of glacial lakes in Little Bitterroot Valley and along Flathead River south of Polson at altitudes of 3,800 feet or more may result from pre-Wisconsin stages of glaciation, possibly when the ice mass advanced past Polson to block Little Bitterroot Valley west of Sloan. He states: "It is significant that so far as the writer (Alden) has observed, the higher shorelines of Lake Missoula--that is, those more than 3,200 feet above sea level--are not present anywhere in Flathead basin north of T. 24 N., in which is the Big Draw. This is in accordance with the suggestion that the higher stages of Glacial Lake Missoula, those between 3,200 and 4,200 feet above sea level, occurred before (and some of them a relatively long time before) the front of the Flathead glacier melted back northward from the Polson moraine."

Ice flow into Swan Valley consisted mainly of alpine glaciers originating along the divide and upper slopes of the Swan Range. From Thunderbolt Mountain, ice moved down the North Fork Lost Creek scouring a terracelike feature high on the south slope at an altitude of 5,400 to 5,600 feet for a distance of 2 miles or more.

This topographic feature, resembling a fault scarp, appears as a northwest-striking fault on the geologic map of Montana. No evidence for the fault is apparent along the North Fork Lost Creek, on the divide at Thunderbolt Mountain, or in Bunker Creek. It is believed the scarplike bench resulted from glacial scour by ice flowing northwestward from Thunderbolt Peak toward Swan Valley.

Sullivan, Bunker and its Middle Fork, Gorge, and Little Salmon Creeks have U-shaped valleys floored with glacial drift, indicating that large valley glaciers moved eastward from Swan divide to the intermontane valley of the South Fork. Cirque lakes and talus slopes near ridge crests attest to alpine-type ice action during late Pleistocene time.

Other alpine glaciers in the Flathead Mountains and Lewis and Clark Range merged to partly fill intermontane valleys with ice. The general direction of ice flow was north or northwest down the Swan, South Fork, and Middle Fork Rivers.

Near the close of the Wisconsin stage, retreating ice in mountain regions deposited ground moraine along valleys and recessional moraines near ridge crests. Meltwater from remaining ice swept through river valleys partly removing outwash deposits and ground moraine to subsequently commence cutting inner valley gorges in bedrock, a process actively taking place today.

The only glacier present in the map area is the Swan glacier, lying at the head of Gorge Creek between Sunburst Lake and Swan Peak at an altitude slightly above 9,000 feet. The ice remnant is a small one on the northeast slope of Swan Peak.

Ice Movement

The Flathead lobe, continuing from the Lakeside-Somers-Bigfork area, advanced southeastward to Rollins, where the Lake Mary Ronan lobe scoured the Dayton bench. Glacial striae southeast of Proctor in the SW$\frac{1}{4}$ sec. 27 and NE$\frac{1}{4}$ sec. 34, T. 25 N., R. 21 W., trend N. 45° W. and N. 40° W. respectively, indicating that the ice moved in a generally northwest direction toward Lake Mary Ronan.

Along the east shore of Flathead Lake, glacial striae indicate a southwest direction of ice flow. Near the mouth of No-See-Um Creek, direction of ice flow was south.

On the western slope of the Swan Range, alpine glaciers from the Swan divide flowed westerly down the North Fork Lost Creek, Bond Creek, and Hall Creek to merge with ice in the Swan Valley, the ice continuing in a N. 40° W. direction down the valley to Bigfork. Between Thunderbolt Mountain and Bunker Lake, glacial striae trend N. 45° to 50° W. and N. 60° W., and a subsidiary set trends N. 75° E. The northwest-striking striae are associated with grooving, polishing, and chatter marks, the chatter marks indicating that ice movement was northwest past Crevice Lake to the head of the North Fork Lost Creek. Other northeast- and southeast-striking striae are believed to indicate ice flowage to the headwaters of Bunker Creek and continuing east to the South Fork. Striations southeast of Thunderbolt Mountain indicate ice flow in a S. 50° E. direction down toward the South Fork.

Striae in Bond Creek in the S$\frac{1}{2}$ sec. 17, T. 25 N., R. 17 W., show that the ice mass moved S. 70° W. On an upper tributary of Hall Creek, ice moved S. 20° E. from near the divide northwest of Hall Lake down Hall Creek to Swan Lake. West of Sixmile Mountain, in sec. 28, T. 26 N., R. 18 W., striae trending N. 40° W. parallel the long axis of Swan Lake.

Glacial Topographic Features

The Flathead glacier, continuing south from Flathead Valley into the depression now occupied by Flathead Lake, was constricted into a narrower passage by the Mission Range, which the east ice margin tended to override between Bigfork and Yellow Bay. On the west shore of the lake, southwest of Rollins, spur ridges extending eastward to the lake shore further confined the mass so that after passing this point a sublobe spread laterally in a northwest direction toward the basin occupied by Lake Mary Ronan.

From a point a mile southwest of Rollins the west ice margin scoured for 1$\frac{1}{2}$ miles a narrow, uniform, sloping bench trending N. 50°-70° W. The bench is visible from U. S. 93 on a bald southeast-facing slope. This Dayton bench is thought to delimit the north margin of the sublobe at an altitude determined by Alden (1953, p. 122) to be 4,200 feet.

The lobe continued northwest, producing a uniform decrease in bench altitude toward Dayton Creek, the bench being particularly well developed between sec. 31, T. 25 N., R. 20 W., and sec. 26, T. 25 N., R. 21 W. Waterworn and striated pebbles and cobbles of glacial origin, glacial erratics of molartooth limestone, and small moundlike deposits of glacial drift occur along the bench. Above, outcrops show no evidence of ice movement.

In sec. 22 and 26, T. 25 N., R. 21 W., two small lakes occupy depressions formed by ice action. The larger, in sec. 26, is impounded by a recessional(?) moraine.

The northwest terminus of the sublobe was located at Lake Mary Ronan; a terminal moraine forms the south and east shores of the lake. The moraine impounded waters that extended for some distance up Hilburn Creek and other lake tributaries, so that lacustrine silts were deposited over local accumulations of outwash. Outwash gravels probably underlie the silts an additional distance up Hilburn Creek, although silt deposits that formerly bordered the west lake shore have been removed by wave action as the lake level fluctuated, thus exposing older glacial drift.

The Ronan moraine extends in a sharply defined ridge and parallel ridges northwestward from sec. 21, T. 25 N., R. 21 W., to sec. 13, T. 25 N., R. 22 W., and continues a short distance farther, but with less pronounced trend and form.

A recessional moraine occurs in the valley of the North Fork Lost Creek east of its junction with the South Fork Lost Creek.

R O C K   T Y P E S

Rocks within the four mapped quadrangles range in age from Precambrian (Belt Series) to deposits of Quaternary age. Sedimentary rocks of Ordovician, Silurian, Pennsylvanian, Triassic, and Jurassic ages are missing either through erosion or nondeposition, or faulting. A few sills and irregular bodies whose composition is dioritic or gabbroic are present in the area. The igneous rocks are thought by Ross (1959) and others to be of Precambrian age, as the Purcell Basalt is genetically related to the similar igneous rocks in the adjacent Flathead and Glacier Park areas.

The lowest exposed Precambrian units are the Appekunny and the conformably overlying Grinnell Formations of the Ravalli Group. Where these two formations are not distinguishable, the Ravalli undifferentiated appears on geologic maps. Conformably overlying the Ravalli Group are three mappable units of the Piegan Group identified as the lower unit P_1, the central unit P_2, and the upper unit P_3. Conformable above Piegan Group strata are Missoula Group sedimentary rocks locally subdivided by Deiss into a lower unit, Miller Peak Argillite; a central unit, Cayuse Limestone; and an upper unit named Ahorn and Hoadley Formations. On Plates 2 and 3 Missoula Group rocks appear as Missoula undifferentiated. An erosional unconformity separating the Precambrian Belt Series from overlying Cambrian strata was recognized and discussed by Peale, Walcott, Deiss, and others.

Middle Cambrian formations in ascending order are Flathead Sandstone, Gordon Shale, Damnation Limestone, Dearborn Limestone, Pagoda Limestone, Pentagon Shale, Steamboat Limestone, and Switchback Shale. The last is overlain by Devils Glen Dolomite (Upper Cambrian).

An erosional disconformity separates the Upper Cambrian formation from overlying Upper Devonian units, which are subdivided into a lower White Ridge and Glenn Creek unit and the Devonian undifferentiated. In parts of the Silvertip and Swan Lake quadrangles where the White Ridge and Glenn Creek were not recognized, all strata between the Cambrian and Mississippian Systems were mapped as Devonian undifferentiated.

Overlying the foregoing with apparent conformity are Mississippian strata that Deiss named Hannan Limestone. They are correlative with the Madison Group of southwest Montana.

In fault contact with Missoula Group rocks are beds of sandstone and shale identified as Kootenai (Cretaceous).

Consolidated and unconsolidated rocks of Cenozoic age include Tertiary clastic deposits, unconsolidated ground moraine and lacustrine silt (Pleistocene), and Recent alluvial gravel, sand, and silt deposited on flood plains adjacent to streams and rivers.

BELT SERIES (PRECAMBRIAN)

Ravalli Group

Appekunny and Grinnell Formations are exposed east and west of Swan Lake on the east slope of the Mission Range and west slope of the Swan Range (Pl. 2). South of Crane Creek in the Mission Range west of Flathead Lake, the two formations could not be recognized as separate units; in these places the Ravalli Group was mapped as Ravalli undifferentiated. Grayish-red-purple argillite and intercalated gray and white quartzite beds (several inches thick) interfinger with medium- and light-gray argillite and quartzose argillite in the upper few thousand feet of Ravalli Group beds near sec. 3, T. 25 N., R. 21 W.

These beds between Flathead Lake and sec. 3 are lithologically similar in color and composition to Grinnell rocks, but because they are locally occurring and discontinuous northwest, they were mapped as Ravalli undifferentiated. In the writer's opinion they represent the westernmost exposure of Grinnell-type rocks in the map areas. For more detailed descriptions of rocks of the Ravalli Group, the reader is referred to Montana Bureau of Mines and Geology Bulletin 36.

Appekunny Formation.--The Appekunny Formation is the lowest exposed unit of the Ravalli Group. It is a thin- to thick-bedded, light-gray and purplish-gray argillite, which is locally greenish gray and quartzose. Some white coarse-grained feldspathic quartzite beds and lenses of variable thickness are included. The argillite on weathered surfaces is light gray to purplish gray. Octahedral magnetite is sporadically present. The Appekunny in the Swan Range is believed to have a thickness of 4,500 feet, but the base is not exposed.

Grinnell Formation.--The Grinnell Formation conformably overlies the Appekunny and is predominantly gray-red-purple to grayish-red argillite containing numerous intercalated beds of locally calcareous grayish-green argillite as much as 20 feet thick. Two-inch beds of feldspathic coarse-grained quartzite are common in the upper part of the Grinnell, and at the base ripple-marked medium-grained purple-banded quartzite beds occur. Mud cracks and intraformational breccias are characteristic and abundant throughout the unit, especially in the red argillite. The Grinnell is at least 4,600 feet and may be as much as 5,500 feet thick in the Swan Range. In the Mission Range the Grinnell is 3,500 feet thick, but the outcrop narrows so abruptly that south of Crane Creek it is no longer mappable.

Ravalli undifferentiated.--Rocks of the Ravalli undifferentiated unit occupy most of the Elmo quadrangle, the west Flathead Lake quadrangle, and parts of the west Swan Lake quadrangle. As in other nearby areas, the base of the Ravalli is not exposed.

Ravalli undifferentiated rocks are equivalent to Ravalli strata mapped in northern and western Flathead County, which are described in Montana Bureau of Mines and Geology Bulletins 29 and 36. The stratigraphic equivalents east of the Trench are the Appekunny and Grinnell Formations of the Ravalli Group.

Ravalli undifferentiated rocks are thin-bedded medium- and light-gray sericitic and noncalcareous mud-cracked argillite and quartzose argillite containing occasional thin layers of light-gray or white quartzite. Interfingering purplish-gray argillite and quartzite is more abundant along the north boundary of the Elmo quadrangle in the vicinity of Kerr Mountain.

From sec. 3, T. 25 N., R. 21 W., southeastward to Flathead Lake the upper few thousand feet of the Ravalli Group show a marked lithologic change through interfingering to thin-bedded, sericitic, mud-cracked grayish-red and dark-red purple-toned argillite and banded argillite containing intercalated light-gray

<table>
<tr><th></th><th>Southern Whitefish Range
Barnes and Smith</th><th>Marias Pass
Childers</th><th>Alberta and British Columbia
Price</th><th>Glacier Park
Ross</th><th>Southeast Flathead County
(this report)</th><th>Southern Swan Range
Walcott</th></tr>
<tr><td>Paleozoic</td><td></td><td></td><td></td><td></td><td>Cambrian</td><td>Cambrian</td></tr>
<tr><td rowspan="5">Missoula Group</td><td>(top eroded)
Roosville
4,000+</td><td rowspan="3">(top faulted)
Unnamed sequence

Red Plume
791

Shields
2,551</td><td>(top eroded)
Roosville
3,500+</td><td rowspan="4">(top eroded)
Undifferentiated

Missoula Group

6,000+</td><td rowspan="5">Undifferentiated

Missoula Group

12,000+</td><td rowspan="5">Camp Creek Series

11,700</td></tr>
<tr><td>Phillips
650-700</td><td>Phillips
500-700</td></tr>
<tr><td>Kintla
2,900-3,300</td><td>Gateway
1,150-3,000</td></tr>
<tr><td>Shepard
400</td><td rowspan="2">Shepard
1,550</td><td>Shepard
(lower Gateway)
150-900</td></tr>
<tr><td>Purcell lava
0-350</td><td>Purcell andesitic lava
0-600</td><td rowspan="2">Purcell Basalt
to 200

Lower Missoula Group
300±</td></tr>
<tr><td rowspan="3">Piegan Group</td><td>Upper
1,200-2,000</td><td>Snowslip
1,400</td><td rowspan="3">Siyeh
1,130-3,000</td><td>Upper
1,000</td><td rowspan="3">Blackfoot Series

5,000</td></tr>
<tr><td>Middle
4,500-5,800</td><td rowspan="2">Siyeh
3,858</td><td>Siyeh
1,800-5,000</td><td>Middle
5,000+</td></tr>
<tr><td>Lower
1,250-3,200</td><td rowspan="2">Grinnell
1,000-4,000</td><td>Lower
1,200-2,400</td></tr>
<tr><td rowspan="3">Ravalli Group</td><td>Grinnell
2,500</td><td>Grinnell
2,400</td><td>Grinnell
350-700</td><td>Grinnell
0-4,600</td><td rowspan="3">Ravalli
8,250

(base not exposed)</td></tr>
<tr><td rowspan="2">Appekunny
5,000+

(base not exposed)</td><td rowspan="2">Appekunny
1,000

(base not exposed)</td><td>Appekunny
1,500-2,000</td><td>Appekunny
2,000-5,000</td><td rowspan="2">Appekunny
4,500

(base not exposed)</td></tr>
<tr><td>Altyn
500-4,000</td><td>Altyn
2,000±
(base not exposed)</td></tr>
<tr><td>Pre-Ravalli rocks</td><td></td><td></td><td>Waterton
1,500
(base faulted)</td><td></td><td></td><td></td></tr>
</table>

Correlation of Belt Series in southeastern Flathead County with nearby areas.

and white quartzite beds. Ripple marks and intraformational breccia are not uncommon, but the latter does form 2- to 3-inch layers parallel to stratification. These Grinnell-like rocks crop out for a distance of 3½ miles.

A similar discontinuous zone of red-toned and dark-purplish-gray argillite occurs below the Ravalli-Piegan contact southeast of Blacktail Mountain, whereas purple, red, and pale-green streaks appear in predominantly gray noncalcareous upper Ravalli rocks for some distance northwest of Blacktail Mountain. These areas were described in Montana Bureau of Mines and Geology Bulletin 36.

It is the opinion of the writer that the position of these discontinuous red-gray-purple rocks described under Ravalli undifferentiated marks the western limit of deposition of Grinnell strata in the map area, these reddish argillite beds having been deposited under similar conditions and derived from the same source area as Grinnell strata farther northeast. The west boundary of the Rocky Mountain Trench approximates the western limit of deposition of Grinnell-type rocks except where modified by local embayments. It seems probable that a northeastern source area of iron-bearing rocks was subjected to subareal erosion, and that anhydrous hematite and turgite formed during deposition produced the distinctive color of Grinnell strata. The green discoloration in the Appekunny possibly represents reduction of ferric iron to ferrous iron after deposition in water, thereby producing the green tinge characteristic of beds in this unit.

Willis' observation (1902, p. 322) that the Grinnell and Appekunny Formations are phases of one formation, the contact being diagonal to bedding, is supported to some extent by field observation in the map area.

In the Mission Range south of Crane Creek, where the Appekunny and Grinnell are no longer mappable units, the Ravalli undifferentiated is a fairly homogeneous sequence of predominantly light- to medium-gray and purplish-gray mud-cracked and banded argillite containing local greenish-gray interbeds. Some fine- to medium-grained quartzite beds are as much as 20 feet thick. Purple banding is common in the quartzite. Magnetite and sericite are sporadically present in argillite that weathers light gray to purplish gray. The strata are locally calcareous. In outcrops, voids after biotite and magnetite are filled with iron oxide.

Piegan Group

The Piegan Group is separated into three units, which are traceable throughout the Elmo, Flathead Lake, and Swan Lake map areas. The lower and upper units, P_1 and P_3 respectively, consist of banded green argillite, sporadically calcareous; the middle P_2 unit is composed of limestone and dolomite. Unit P_2 is equivalent to Ross' Siyeh Formation, and the Piegan Group as a whole is approximately equivalent to the Blackfoot Series of Walcott (1906, p. 10) in the Swan Range.

P_1 Unit.--Conformably overlying the Grinnell Formation is the basal unit P_1, which Ross (1959) maps as a transition zone between the Ravalli and Piegan Groups. This P_1 unit is a thin-bedded and laminated pale-blue-green and pale-green mud-cracked argillite, sporadically calcareous. Within the unit are light-gray limestone lenses and sparse 2-inch beds of coarse-grained white quartzite. Near the center are two 10-foot beds of grayish-red argillite. The upper 500 feet of the P_1 unit is a presistent pale-blue-green to greenish-gray argillite and calcareous argillite weathering greenish gray and yellow gray. Locally, 2-inch pyrite cubes are abundant. In the Mission Range the unit is faintly to moderately banded and locally mud cracked and contains intraformational breccias.

In the Swan Range the P_1 unit is about 1,800 feet thick. It is 2,400 feet thick in the Mission Range and 1,200 feet thick west of Flathead Lake. The unit thickens northwestward from Rollins toward Kerr Mountain, and north of Blacktail Mountain the unit is about 3,000 feet thick.

A thin transition zone of interbedded medium-gray limestone and blue- to greenish-gray argillite containing pyrite cubes is conformably overlain by the P_2 unit.

P_2 Unit.--The central unit (P_2) of the Piegan Group (Ross' Siyeh Formation) is predominantly a fine crystalline medium-gray and light-gray molar-tooth limestone and dolomite. The color darkens locally to almost black, although some argillaceous zones are light gray. The unit is thick bedded and massive except that the uppermost part of the unit contains some thin-bedded zones of limestone lacking molar-tooth structure. It ordinarily weathers grayish orange, but light-gray weathering is common where solution holes accentuate bedding. About 2,500 feet below the P_2-P_3 contact is a bed containing large and abundant stromatolite heads.

More than 5,000 feet and possibly as much as 7,500 feet of this middle limestone unit is exposed in the Swan Range. An incomplete section of P_2, the top being an erosion surface, crops out west of Flathead Lake.

P_3 Unit.--Overlying the middle limestone is the upper unit (P_3) which is exposed along the crest of the Swan divide. It consists of pale-green and grayish-green thin-bedded and laminated argillite, calcareous argillite, and dolomitic limestone. Mud cracks and mud breccia are moderately abundant. The rocks weather grayish orange and yellow brown. Local solution holes etch the bedding to give the rock a pocky appearance.

These upper strata of the Piegan Group are at least 1,000 feet thick, but a wide transitional contact zone between the middle and upper units makes it difficult to place a contact, as rocks of composition similar to both middle and upper units occupy this zone. Unit P_3 is in large part equivalent to basal Missoula member P€ca of Ross' Flathead and Glacier Park area. The upper P_3 contact is sharply transitional into mud-cracked red argillite of the conformably overlying Missoula Group.

Missoula Group

A thick group of fine clastic rocks exposed east of the city of Missoula was named the Missoula Group by Clapp and Deiss (1931, p. 677). In this area the group was divided into five units, later redefined by Nelson and Dobell (1961), which in ascending order are the Miller Peak Argillite, Bonner Quartzite, McNamera Argillite, Garnet Range Quartzite, and Pilcher Quartzite, amounting to a total group thickness of 15,550 feet. In Lincoln County, northwest Montana, the Missoula Group is represented by the Striped Peak and overlying Libby Formations, which have a total thickness of 8,000 feet or more. Within the Whitefish Range the Missoula Group has been divided by Smith and Barnes (Johns and others, 1963, p. 28) into the Shepard, Kintla, Phillips, and Roosville Formations, in ascending order totaling 8,400 feet in thickness. Within the southwest Saypo quadrangle, Deiss (1943a, p. 211-218) divided the Missoula Group into four formations, which from the base upward are: Miller Peak Argillite, Cayuse Limestone, Hoadley Formation, and Ahorn Quartzite, the Miller Peak Argillite having been traced from its type section on Miller Peak in the Bonner quadrangle to the central Lewis and Clark Range. He assigned a thickness of 8,200 feet for the group in the southwest Saypo area. In recent work within the Lewis and Clark Range, D. A. Sommers (personal communication) assigns a tentative thickness of 7,000 to 7,300 feet for Miller Peak strata between the Siyeh Formation and Ahorn Quartzite.

In the southwest Saypo quadrangle Deiss (1943a, p. 215) describes the Miller Peak Argillite as pale-green and maroon fissile siliceous argillite overlain by red and green sandy and ripple-marked argillite and thin beds of fine-grained quartzite, and some buff-tan dolomite and quartzose sandstone. Overlaying this sequence is several hundred feet of interlayered tan-weathered dolomitic and quartzose sandstone, some red and green argillite forming a transition zone between clastic strata below and carbonate-bearing strata above. Deiss estimates the thickness to be 1,000 feet, but the lower part of the unit is cut out by the Lewis and Clark thrust.

Above the Miller Peak is the Cayuse Limestone, described as finely crystalline, siliceous, dull- to pale-gray dolomite interbedded with maroon and green-gray fissile argillite containing several beds of gray coarse-grained quartzite; some of the dolomite surfaces weather to simulate molar-tooth structure.

Stratigraphically higher is brown-weathering gray dolomite interbedded with black-gray fissile argillite. Overlying the dolomite are alternating zones of calcareous and dolomitic argillite and sideritic and dolomitic marble, followed by blue and dull-gray oolitic limestone and thick-bedded crystalline limestone. At the top is a thin-bedded algal limestone, the algal heads ranging from 6 to 30 inches in diameter.

Deiss (1943a, p. 216) gives a thickness of 1,000 feet for the Cayuse Limestone. This figure was determined from reconnaissance traverses across strike and by thickness scaled from the map.

Conformably overlying the Cayuse is 4,100 feet of strata that Deiss (1943a, p. 217) assigned to the Hoadley Formation, which he describes as green, green-gray, and maroon argillite and fine-grained argillaceous quartzite weathering gray and green. Stratigraphically above the basal unit is buff arenaceous and calcareous argillite and sandstone gradational to pale-green calcareous sandstone and argillite. Overlying these strata are interbedded red, pink, and buff sandstone and argillite. Above the red and pink sandstone is another buff-weathering calcareous, sericitic, and limonite-stained argillite and argillaceous limestone sequence followed by an upper dark- and brilliant-red soft ripple-marked sandstone interbedded with arenaceous pale-red argillite.

The uppermost unit of the Missoula Group is the Ahorn Quartzite, which Deiss named as the youngest of the formations. It underlies the Flathead Quartzite (Middle Cambrian) in the southwest part of the Saypo quadrangle. He gave an estimated thickness of 2,100 feet for the Ahorn, and described a lower pink and pale-maroon cross-bedded vitreous thick-bedded quartzite and an upper green and red argillite (Deiss, 1943a, p. 218). The upper unit is dominantly an interbedded green and green-gray fissile argillite containing some thin-bedded red-gray argillite and a few intercalated fine-grained sandstone zones.

Within the Swan Lake and Silvertip areas a thick body of essentially clastic maroon sediments is assigned to the Missoula Group undifferentiated. The assemblage contains some gray limestone and calcareous argillite, notably a thick body in the lower part of the group, interbedded with the predominantly clastic rocks.

The Missoula Group occupies the east flank of the Swan Range and crops out in the Flathead and Lewis and Clark Ranges in northward-trending belts from longitude 113°30' eastward to the Continental Divide. In the Silvertip NE quadrangle it extends to the trace of the Lewis overthrust.

<u>Missoula Group undifferentiated</u>.--A comparatively narrow transitional zone separates the underlying pale-green and gray-green banded slightly calcareous argillite of the uppermost

Piegan Group from ripple-marked thin- to medium-bedded grayish-red argillite of the basal part of the Missoula Group. The lower strata of the Missoula Group along east-west ridge lines separated by Bunker Creek consist of grayish-red and pale-red argillite, sandy argillite, and sandstone, interlayered with a few beds of light-gray quartzite, followed by thin-bedded and laminated pale-green to grayish-green argillite and slightly calcareous argillite and maroon and grayish-red ripple-marked and mud-cracked argillite. Mud breccia is present, and a few beds of pale-pink and grayish-green argillite and quartzite are intercalated. Two zones of pale-green and grayish-green laminated argillite in this sequence are separated by grayish-red and maroon argillite and quartzite. This entire sequence of sedimentary rocks is about 2,000 feet thick and is believed to be correlative with Deiss' Miller Peak Argillite.

Conformably overlying these red strata is about 1,000 feet of limestone. It comprises finely crystalline medium- and light-gray limestone, pale-green and gray-green limestone, and argillaceous limestone weathering yellow brown, medium gray, and light gray, all interbedded with gray argillite and calcareous argillite. A few beds of gray and grayish-red quartzite are present as are a few 3-inch stromatolite beds. This unit may be equivalent to Deiss' Cayuse Limestone. Weathering and solution simulates molar-tooth structure in some limestone. An indented or pockey yellow-brown weathered surface is characteristic of the limestones in this sequence.

Conformably overlying the carbonate strata is about 3,000 feet of clastic rock. It comprises maroon and pale-red commonly ripple-marked and sericitic argillite and quartzite argillite, light-gray quartzite, and a few beds of purplish-gray laminated argillite and mud-cracked argillite. These red and gray beds are followed by a relatively thick quartzite unit, which includes thin- and thick-bedded, grayish-red and medium-light-gray to white medium-grained quartzite, interbedded with grayish-red and gray sandstone toward the top.

Overlying the quartzite are rocks of varied composition several thousand feet thick. They include thin-bedded medium- and light-gray quartzite and argillite and a few interbeds of dark- to light-gray limestone weathering pale yellow. Grayish-red fissile argillite and thin-bedded sericitic quartzite, much of it banded, mud cracked, and ripple marked, are included in this sequence. At the top of the unit, underlying Paleozoic strata, are medium-light-gray, pale-green and greenish-gray sandstone, quartzite, and argillaceous quartzite or argillite several hundred feet thick. The green and gray weathered sandstone beds are feldspathic in some areas. Thin glauconite-bearing beds have been reported from this sequence in the Lewis and Clark Range (D. A. Sommers, personal communication). In the area west of Beacon Mountain and extending to the South Fork (north of Spotted Bear), the uppermost Missoula beds underlying the Flathead Quartzite are pale-green faintly banded thin-bedded and fissile sericitic argillite weathering green gray interbedded with grayish-red thin-bedded quartzite and argillite weathering light grayish red. A few thin beds of green stromatolitic limestone and calcareous argillite weathering grayish orange are present.

Limestone beds within the Missoula Group seem to be discontinuous and ordinarily cannot be traced for any great distance within the Swan Lake map area; this comment seems to be also applicable to the limestone unit (Cayuse Limestone) that Deiss mapped in the Silvertip quadrangle.

The total thickness of the Missoula Group was graphically scaled to be about 12,000 feet and may be as much as 14,400 feet in the Swan Range.

PALEOZOIC

Prior to 1931 two sections of Cambrian rocks in northwest Montana had been published, one measured on the Dearborn River and one at Gordon Mountain (Walcott, 1917b, p. 16-19).

Beginning in 1931 with areal geologic mapping of the Coopers Lake quadrangle, Deiss and his co-workers did detailed and reconnaissance studies of Paleozoic rocks in northwest Montana. His studies of Cambrian, Devonian, and Mississippian units continued without interruption until 1936, and then intermittently until 1943, when reports on the southwest Saypo quadrangle and Sawtooth Range were published. During this latter period the Silvertip quadrangle was mapped, geologic data for the Silvertip map being compiled by Deiss in April 1947.

Mississippian and Devonian strata in northwestern Montana were studied by Sloss and Laird prior to 1947. In their reports, unnamed Devonian members are designated by letter and number, and a late Devonian age was assigned to these strata, based on paleontologic evidence.

From detailed work in the Flathead, Lewis and Clark, and Sawtooth Ranges, Deiss subdivided the Middle and Upper Cambrian units, totaling 1,700 to 2,000 feet in thickness, into nine named formations, and the Devonian, totaling about 1,000 feet, into two or more named formations (two unnamed units of late Devonian age in the Sawtooth Range). A Mississippian limestone, whose surface is an erosional one in the Swan Lake and Silvertip quadrangles, was named by Deiss the Hannan Limestone. In the Sawtooth Range the Mississippian rocks range in thickness from 1,230 to 1,700 feet.

Paleozoic rocks, especially Cambrian cliff-forming limestone, contrast in topograhic expression and in color to the more subdued Belt rocks of the underlying Missoula Group. In late afternoon sunlight, west-facing Paleozoic cliffs seen from a distance exhibit a distinctive pale yellowish gray, above underlying Belt strata that are dark grayish red or dark gray.

Paleozoic sedimentary rocks of Cambrian, Devonian, and Mississippian age crop out in the Silvertip quadrangle and in the Swan Lake NE quadrangle (Pl. 2 and 3). Within the Silvertip area Paleozoic rocks occur as northwest-oriented belts paralleling the western side of the South Fork Flathead River between Big Salmon Lake and Meadow Creek landing field; the east side of the South Fork from Black Bear Creek to the northwest corner of the quadrangle; and on the western slope of the Continental Divide from the Flathead-Powell County line north to Whitcomb Peak. Another belt of Paleozoic rocks follows the Continental Divide from the head of Spotted Bear River north past Pentagon Mountain, thence beyond Cruiser Mountain to latitude 48°. Outcrops of the Paleozoic strata are separated by exposures of Beltian rocks of the Missoula Group in parallel pattern.

Northeast of Spotted Bear a small mass of Paleozoic sediments crops out in the northeast corner of the Swan Lake quadrangle (Pl. 2).

Ordovician and Silurian sedimentary rocks are absent within the mapped quadrangles, as they are throughout Montana west of the Continental Divide.

Cambrian

Flathead Quartzite.--The Flathead was named by Weed (1900, p. 285) for the occurrence in the Little Belt Mountains. It was later amended by Deiss (1936, p. 1328) for central Montana, to be generally applicable to the Flathead in northwest Montana. In the map area and throughout Montana it is the lowest Cambrian unit exposed and is of Middle Cambrian age.

Within the map areas the Flathead Quartzite and overlying Gordon Shale combined are only 250 to 300 feet thick; the scale of the U. S. Geological Survey Silvertip topographic sheet prohibited mapping them separately. In some places the contact between the formations is covered. These units were not discernible at the base of exposed Middle Cambrian limestone west of the South Fork between Big Salmon Lake and Meadow Creek, because of nondeposition, because of faulting, or because the Flathead and Gordon are completely covered in this area; this last possibility seems unlikely.

Flathead and Gordon beds crop out in the Swan Lake NE quadrangle east of the South Fork on the west slope of Beacon Mountain.

The Flathead Quartzite is a medium-grained light-brown cross-bedded, limonite-flecked, thin- to thick-bedded unit consisting mostly of quartz sand and white, tan, and colorless pebbles. Some limonite blebs occur in bedding planes. In some

	Silvertip quadrangle, Pentagon Mountain (Deiss, 1938)	Central Saypo quadrangle (Deiss, 1943b)	Lewis and Clark Range (Sloss and Laird, 1945)	Sawtooth Range (Mississippian Units in Sun River Canyon after Mudge and others, 1962)
Mississippian	Hannan Limestone	Hannan Limestone	Unit MA	Madison Group: Castle Reef Dolomite
			Unit MB_1	
			Unit MB_2	Madison Group: Allan Mountain Limestone
	Silvertip Member at base	Silvertip Member at base	Unit MC	
Upper Devonian	Devonian undifferentiated (In early work divided into three members)	Devonian undifferentiated (Two new unnamed formations)	Unit DA_1	
			Unit DA_2	
			Unit DB	
	White Ridge Limestone		Unit DC	
Disconformity				
Upper Cambrian	Devils Glen Dolomite	Devils Glen Dolomite	Devils Glen Dolomite	
Middle Cambrian	Switchback Shale	Switchback Shale		
	Steamboat Limestone	Steamboat Limestone		
	Pentagon Shale	Pagoda Limestone (Base not exposed)		
	Pagoda Limestone			
	Dearborn Limestone			
	Damnation Limestone			
	Gordon Shale			
	Flathead Sandstone			
Unconformity				

Paleozoic strata in Lewis and Clark and Sawtooth Ranges.

localities the unit has a basal bed of cross-bedded material as much as 5 feet thick containing white, tan, and colorless pebbles averaging 3/8 inch in diameter.

The Flathead Quartzite does not form conspicuous cliffs as does the overlying Middle Cambrian limestone, probably because of its restricted thickness, which averages about 77 feet in the Silvertip quadrangle. Deiss (1939, p. 36) gives an average thickness of 94 feet for northwest Montana, but only 35 feet is exposed on Whitcomb Peak, where the base of the sandstone is believed to have been cut out by a north-striking fault.

The upper half of the Flathead is more sandy, and near the top of the unit sand and shale zones are interbedded. The contact between the Flathead and Gordon is a transitional one, and previous workers have placed the contact zone at the base of the first consistent shale, although occasional sandy zones may occur above the contact.

Middle Cambrian Flathead Quartzite rests with apparent conformity on Precambrian Beltian rocks of the upper part of the Missoula Group, but by tracing the Beltian-Cambrian contact along strike and by studying additional localities where the contact between the two systems is exposed, Walcott, Burling, and Deiss postulated an erosional unconformity between upper Belt rocks and Cambrian sandstone in northwest Montana. Deiss (1933, p. 50) believed that about 9,000 feet of upper Missoula Group beds were removed by erosion prior to deposition of Flathead Quartzite.

Slight angular discordances between Cambrian and Beltian rocks at Steamboat Mountain, Prairie Reef, Haystack Mountain, and at the head of Ford Creek were described by Deiss (1933, p. 48). All these localities are in the Lewis and Clark Range southeast of the map area. Deiss estimated the angular unconformity at Prairie Reef to be 5° to 7°, and that at the Ford Creek cirque 8° to 11°.

Ross (1963, p. 99-103) demonstrated that not everywhere is the boundary between Precambrian and Cambrian rocks marked by an angular unconformity, and in areas where a discordance is recorded, the angularity is not great. He stated that Walcott and Deiss mainly used evidence of regional overlap instead of angular discordance to postulate the break in sedimentation between Precambrian and Cambrian rocks. Ross stated further that the best supported evidence for unconformity in and adjacent to Montana occurs near the postulated border of the original Belt basin.

Gordon Shale.--The name Gordon was proposed by Walcott (1917a, p. 7) for a Middle Cambrian green-purple fossiliferous shale containing intercalated sandstone and limestone beds and overlying the Flathead Quartzite. The type locality is 14 miles southeast of Big Salmon Lake on the south side of Kid Mountain and on the ridge between Gordon and Young Creeks in the Ovando quadrangle. The fine argillaceous shale carries the Albertella fauna, which differs from the known fauna in the lower shale of the Dearborn and Little Belt Mountain sections. Therefore, Walcott (1917b, p. 16) named this shale the Gordon Shale rather than the Wolsey Shale, which is the name of the unit that occupies the same stratigraphic position in central and southwestern Montana.

Deiss (1936, p. 1328) emended the definition of the Wolsey Shale of central Montana and stated that it applied in most particulars to the Gordon Shale of northwest Montana (Deiss, 1939, p. 37). He wrote (1939, p. 38):

"The most notable differences between the Gordon and Wolsey Shales is the absence from the Gordon of numerous extremely fossiliferous limestone lenses, the slightly greater proportion of limestone and sandstone in thicker beds in the upper middle part of the formation, and the absence or paucity of fossils in the limestones and sandstones."

At its type locality near Gordon Mountain the shale is 284 feet thick, and Deiss gave an average thickness of 221 feet (1939, p. 38) for ten sections where the Gordon Shale is exposed.

The Gordon is soft grayish-brown and greenish-gray fissile shale weathering greenish gray and containing intercalated sandstone lenses in the lower third of the formation and a few limestone zones in the upper half of the unit. The formation forms swales and benches where it crosses ridges or mountain slopes. Trilobite fragments and brachiopods are abundant in certain zones.

On Whitcomb Peak in the Silvertip NW quadrangle, a pace-and-brunton survey of an incomplete section of the Flathead Quartzite and the complete Gordon Shale gave an approximate thickness of 35 feet (faulting cuts out the basal part of the unit) for the Flathead and about 345 feet for the Gordon (Fig. 4). The above-average thickness of the Gordon Shale may result from local thickening or from repitition through faulting.

The lower 30 feet of the Gordon is green fissile shale containing brachiopods. It overlies cross-bedded white sandstone of the Flathead. Above the shale is a 10-foot zone of thin- and medium-bedded hematite-bearing grayish-red and white cross-bedded quartzite sandstone overlain by about 95 feet of fissile green shale that weathers pale green. Near the center of the unit is a 20-foot lens of reddish quartzite, which is overlain by green and maroon fissile shale approximately 190 feet thick. This upper shale unit includes several thin limestone lenses, one of which is 2 feet thick, and contains brachiopods and trilobite fragments. It is conformably overlain by the massive dark- and medium-gray cliff-forming Damnation Limestone.

Cambrian undifferentiated.--Between the Middle Cambrian Flathead and Gordon and the Upper Cambrian Devils Glen Dolomite are six conformable formations whose type localities are within the Lewis and Clark Range northwest of Monitor Mountain. They are, in ascending order , Damnation Limestone, Dearborn Limestone, Pagoda Limestone, Pentagon Shale, Steamboat Limestone, and Switchback Shale. Where the nine units of Middle and Upper Cambrian age, including the basal sandstone and shale and upper dolomite, were undivided the formations were mapped as Cambrian undifferentiated.

The Damnation Limestone, which conformably overlies the Gordon Shale, averages 155 feet in thickness within the area where Deiss measured stratigraphic sections (Silvertip, Ovando, and Coopers Lake quadrangles). The lower one-quarter of the unit is dull-blue or tan-gray fossiliferous and oolitic limestone containing buff clay disseminated as nodules or flakes within the limestone. The upper three-quarters of the formation is thin- and thick-bedded cliff-forming chocolate-gray and tan limestone containing siliceous and arenaceous orange and buff clay flakes. The type section is at the west end of Scapegoat basin in the Coopers Lake quadrangle.

Conformably overlying the Damnation Limestone is the Dearborn Limestone, consisting of a lower shaly section and a thicker limestone section above. Within the area where Deiss measured sections, he gave (1939, p. 40) an average thickness of 298 feet for this formation.

Basal green fissile shale with limestone conglomerate beds intercalated is overlain by green fissile shale and limestone containing, in some areas, interbedded calcareous sandstones. The upper part of the Dearborn is gray, chocolate-gray, and tan thin- and thick-bedded limestone containing light-colored sandy nodules and clay flakes in some sections. The type locality for the Dearborn Limestone is on the north slope of the North Fork of Dearborn River in the Coopers Lake quadrangle. Sixteen species of trilobites have been identified by Deiss (1939, p. 39) in the lower part of the formation.

The Dearborn Limestone is transitional into the conformably overlying Pagoda Limestone, which consists of a thin-bedded shaly basal unit overlain by a thick-bedded partly oolitic limestone. Thickness of the Pagoda averages 305 feet. The type locality is the upper southeast slope of Prairie Reef.

In the lower 70 or 75 feet, beds of dull-green fissile shale are interlayered with gray, green-gray, and tan, sandy and pure limestone containing buff and olive-green clay nodules and flakes. The upper part of the Pagoda is thin- and thick-bedded cream-color and chocolate-gray fine-grained limestone whose central part is oolitic. Deiss lists 24 species of trilobites collected from the Pagoda Limestone.

Pentagon Shale in the eastern part of the map area extends for an undetermined distance north of Pentagon Mountain, and to the south the unit was traced for a distance of 14 miles (Deiss, 1939, p. 42). Thickness of the Pentagon Shale ranges from 75 to 290 feet. This shale unit is not recognizable in the central and south parts of northwest Montana south of Cliff Mountain, 18 miles south of Pentagon Mountain. Its type locality is 2 miles southeast of Pentagon Mountain along the Continental Divide of the Lewis and Clark Range.

The formation is conformable on the Pagoda Limestone. It consists of a bottom member of calcareous gray and buff-tan-gray thick-bedded platy shale interlayered with blue-gray platy limestone, overlain by tan and blue-gray argillaceous limestone. Above the limestone is black-gray paper shale, becoming green brown toward the top, interbedded with thin limestone beds near the base and containing a thick limestone bed near the top. White-gray and chocolate nodular and platy argillaceous limestone makes up the uppermost 26 feet of the Pentagon Shale. Trilobites and brachiopods are concentrated in large numbers in the lower half and uppermost part of this member.

Stratigraphically overlying the Pentagon Shale is the Steamboat Limestone, which crops out in the north map area. The Steamboat Formation, however, conformably overlies the Pagoda Limestone in the south map area where the Pentagon Shale is absent. Thickness of the Steamboat Formation averages 274 feet. The type section is on the crest of Prairie Reef in the Silvertip SE quadrangle, 5 miles east of the map boundary.

The Steamboat Limestone is a medium- and dark-gray massive to thick-bedded cliff-forming formation containing several layers of dull-green fissile shale and shaly limestone. The position of this formation below the Switchback Shale and above the Pagoda or the Pentagon serves to distinguish this formation in the Silvertip quadrangle and throughout adjacent quadrangles. Deiss lists 14 species of the Kochaspis upis fauna as characteristic of this formation.

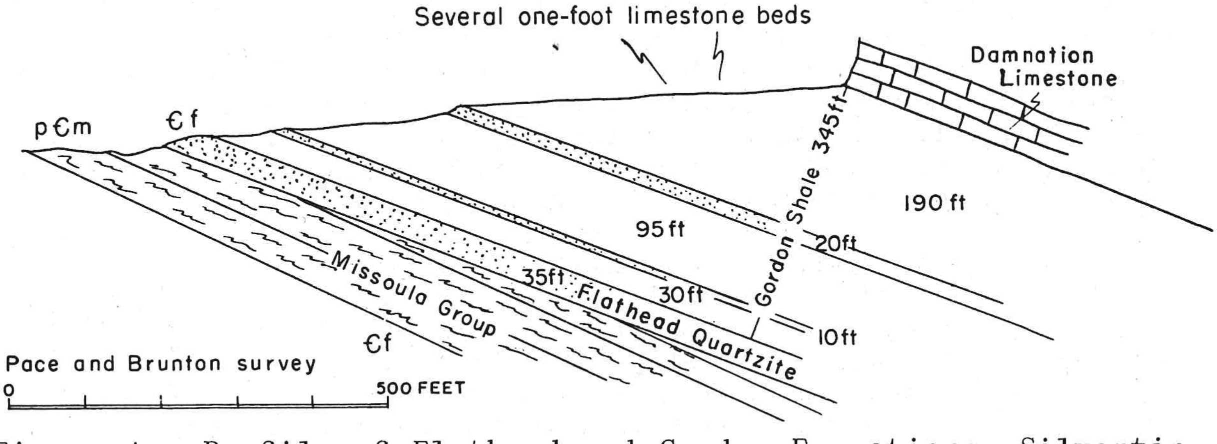

Figure 4.--Profile of Flathead and Gordon Formations, Silvertip quadrangle.

Conformably overlying the Steamboat Limestone is the Switchback Shale. It attains a maximum thickness of 253 feet east of Kid Mountain, but the average thickness in other sections is 111 feet. The type section is in the Ovando quadrangle on a ridge east of Kid Mountain and on the southwest flank of Gordon Mountain in the SW$\frac{1}{4}$ sec. 9, T. 19 N., R. 13 W. Deiss mentioned only unidentifiable fossil fragments found in the limestone beds of the Switchback Shale.

The formation is dominantly soft and fissile green and gray slightly calcareous and arenaceous shale interbedded with gray crystalline rusty-weathering limestone in the lower third to half of the formation. The upper part of the unit is gray and brown arenaceous fine-grained magnesian limestone forming angular fragments and weathering buff.

Above and conformable with the Switchback Shale is the Devils Glen Dolomite--an Upper Cambrian formation and the highest Cambrain unit in northwest Montana. The formation is transitional downward into the Switchback Formation. The minimum thickness measured is 179 feet at Pentagon Mountain, but the thickness averages 353 feet throughout northwest Montana. Deiss attributes the large variation in thickness of the unit to erosion occurring between Late Cambrian and Devonian time rather than to differential deposition of this top Cambrian formation.

<u>Devils Glen Dolomite</u>.--Deiss (1933, p. 40) named this upper unit of Late Cambrian age the Devils Glen Dolomite from its type locality on a north spur of Monitor Mountain near Devils Glen, an inaccessible boulder-filled canyon on the North Fork of Dearborn River. From the vicinity of Pentagon Mountain, where it is 179 feet thick, this dolomite thickens to the Dearborn River, where it attains a thickness of 565 feet. Deiss gives an average thickness of 353 feet for the formation throughout northwest Montana. It conformably overlies the Switchback Shale, but an erosional unconformity separates the Devils Glen from overlying Devonian rocks. In early work Deiss assigned the Switchback Shale and conformable Devils Glen Dolomite to Middle Cambrian, because only fragmentary unidentifiable fossils were found in the shale and none were found in the dolomite, hence the only available fossil evidence, that from the older underlying units, indicated a Middle Cambrian age. Additional evidence from lithic composition and stratigraphic relations with the Eldon Formation of British Columbia supported his conclusion at that time. At a later date, Deiss (1938, p. 1076) assigned the Devils Glen Dolomite a Late Cambrian age.

The formation is unfossiliferous, thick-bedded and massive, cliff-forming white-gray dolomite weathering to a dull grayish white; the lower part is thinner bedded and contains smaller amounts of magnesia. Locally, the dolomite surfaces are spotted pink, and Deiss reports that several thin sections examined microscopically contained finely disseminated quartz grains.

In the Twin Creek area of the Swan Lake NE quadrangle, beds tentatively identified as Devils Glen Dolomite are medium-gray thin- and medium-bedded cliff-forming finely crystalline limestone and dolomitic limestone weathering light gray. The weathered surfaces contain yellow spots and irregular yellow cavities. Some 3-inch beds of conglomerate and feldspathic quartzose sandstone are present. Directly below are beds of shale and shaly limestone.

Devonian

In the eastern Silvertip quadrangle Deiss subdivided Devonian strata into two mappable units, White Ridge and Glenn Creek, but other Devonian strata are mapped as Devonian limestone undifferentiated. In the Silvertip NW area and Swan Lake NE quadrangle, Devonian strata were not subdivided, and Devonian rocks are mapped as Devonian undifferentiated. In a subsequent publication Deiss (1943a, p. 228) reassigned Devonian strata in northwest Montana to an unnamed formation of Late Devonian age. In the Silvertip area, Deiss mapped the combined White Ridge and Glenn Creek members as a unit (Dwg); they appear on Plate 3 as a formation but lose their identity northward. This unit may continue south into the Ovando quadrangle.

While studying Devonian rocks in central and northwest Montana during 1944 and 1945, Sloss and Laird recognized that stratigraphic terminology in central Montana was not applicable to the northwest section of the state. Devonian strata encountered by drilling were assigned to units designated by letter and number (Sloss and Laird, 1947, p. 1418). These are Devonian units C, B, and A from base to top, Unit A being further subdivided into a lower A_2 unit and an upper A_1 unit.

Sloss and Laird described an erosional disconformity between Devils Glen Dolomite (Cambrian) and the basal Devonian Unit C, Unit C strata having been deposited on a channeled Cambrian surface. They correlated Unit C with the Glenn Creek-White Ridge Formation of Deiss and believed that these members can be recognized only locally (1947, p. 1419).

White Ridge-Glenn Creek limestone and shale.--The combined White Ridge-Glenn Creek Formation has its type locality on White Ridge on the 113° meridian at the head of Glenn Creek, tributary of the North Fork Sun River and about 6 miles east of the Continental Divide. Here on the southern flank of the southwestern peak of White Ridge, the Glenn Creek Shale overlies the White Ridge Limestone, the names of the members being taken from Glenn Creek and White Ridge on the north-south border between the Silvertip and Saypo U. S. Geological Survey topographic sheets.

The White Ridge Limestone thins northward from Gordon Mountain (150 feet thick) to Spotted Bear Mountain (50 feet thick); average thickness is 65 feet. The Glenn Creek Shale at its type locality is 66 feet thick, but it thins northward to disappear in the vicinity of Pentagon Mountain. On White Ridge the thickness of the combined units is 129 feet.

At the type locality the lower third of the White Ridge is thin-bedded calcareous gray sandstone. The upper two-thirds consists of thin-bedded and massive brown fine-grained argillaceous limestone.

Deiss (1933, p. 42) described the Glenn Creek Shale as the most conspicuous member of the Devonian in this northwest region where it includes basal beds of dull-red thick-bedded calcareous shale and argillaceous to shaly red-gray limestone. The rest of the section includes thin-bedded red clay shale, green-gray fissile shale, red calcareous shale, gray argillaceous limestone, and capping the section, argillaceous lavender-red limestone.

Unit C of Sloss and Laird (1947, p. 1419) is described as red and green dolomitic shale and mudstone interbedded with brown and reddish-brown sandy and argillaceous dolomite, the unit forming a conspicuous bench between Devils Glen (Cambrian) Dolomite and the cliff-forming Devonian limestone above. It is about 400 feet thick at its western margin of exposure on the eastern slope of the Swan Range.

Upper Devonian limestone undifferentiated.--Within the Silvertip quadrangle the undifferentiated Devonian section includes Deiss' Coopers Lake, Lone Butte, and Spotted Bear Limestones, whose type localities are the southwest peak of White Ridge, on Lone Butte, and at Spotted Bear Mountain, respectively. The Coopers Lake Member was described by Sloss and Laird (1947, p. 1420) as appearing to be equivalent to their Devonian Unit B. The Lone Butte and Spotted Bear Member and the basal conglomerate of the Mississippian limestone (Silvertip breccia-conglomerate) are equivalent to A_1 and A_2 units of Devonian Unit A. In the northwest part of the Silvertip area and the northeast corner of the Swan Lake quadrangle, where the White Ridge and Glenn Creek unit loses its identity, all Devonian strata are mapped as Devonian undifferentiated.

Deiss reported various cumulative thicknesses for the limestone members, ranging from 594 feet to about 1,570 feet, the average thickness being about 1,130 feet for the three units and about 1,260 feet for the entire Devonian. Sloss and Laird (1947, p. 1419) reported thicknesses of 460 to 650 feet for Unit B and 440 to 695 feet for Unit A, the total for the two units ranging from 900 to 1,345 feet. For the Slategoat Mountain section (sec. 10, T. 22 N., R. 11 W.) Sloss and Laird reported thicknesses of 255 feet for Unit C, 460 feet for Unit B, and 612 feet for Unit A, the total thickness for the Devonian amounting to 1,327 feet. It is to be expected that this latter figure would be greater than the total Devonian estimated by Deiss, because it includes some beds (Silvertip breccia-conglomerate) that Deiss mapped as basal Mississippian strata.

Upper Devonian limestone undifferentiated consists of basal beds of thick-bedded to massive brown sandy limestone, becoming in some zones a calcareous sandstone interbedded with thin layers of buff shale, overlain by thick-bedded to shaly fossiliferous tan-gray limestone, which is in turn overlain by thick-bedded to massive fine-grained chocolate to tan limestone. Some interbeds of calcareous clay shale are associated with the basal part of the chocolate-tan limestone. The upper limestone zones are in part petroliferous; when the rock is broken a fetid odor characteristic of Devonian strata is given off. The upper zones tend to weather gray and buff. The fossiliferous tan-gray limestone contains brachiopods, corals, and stromatoporoids of Jefferson age. This part represents about 337 feet of section equivalent to Deiss' Coopers Lake Member.

Above these strata are thin- to thick-bedded petroliferous, vitreous, dolomitic and arenaceous fine-grained, tan, steel-gray, and brown-gray limestone and magnesian limestone weathering drab brown, yellow brown, and white buff. This part of the section, approximately 420 feet of Devonian strata, is equivalent to Deiss' Lone Butte Member.

Overlying the brown vitreous and massive limestone is massive gray, tan-gray, brown-gray, and yellow-white crystalline limestone, weathering gray. Fossiliferous zones contain gastropods, cephalopods, fenestellid bryozoans, and corals. This limestone represents about 287 feet of the Spotted Bear Mountain section. It underlies a conglomerate zone, which Deiss named the "Silvertip conglomerate" and assigned to the basal Mississippian. Sloss and Laird (1945, 1947, p. 1420) interpret the "conglomerate" as evaporite-solution breccias of Devonian Unit A, subdivided into A_1, the upper breccia zone, and A_2, the lower nonbrecciated dolomite.

In the Swan Lake NE quadrangle occurs a 35-foot breccia zone believed correlative with Deiss' Silvertip breccia conglomerate and part of the "evaporite-solution breccias" that Sloss and Laird (1947, p. 1422) named and assigned a late Devonian age. The writer recognizes that this breccia may be of late Devonian age, but to maintain mapping continuity between the Silvertip and Swan Lake quadrangles, has assigned it to the basal Mississippian, following Deiss' stratigraphic nomenclature.

Devonian Unit B of Sloss and Laird was described as mostly brown and brown-gray dense cliff-forming limestone containing a few thin zones of saccharoidal dolomite and somewhat argillaceous near the base of the unit. Stromatoporoids, brachiopods, and corals were reported within the unit.

Devonian Unit A includes nonbrecciated dark- to light-brown and gray dense and massive dolomite and minor dolomitic limestone (Unit A_2) overlain by the uppermost Devonian Unit A_1, consisting of brown, gray-brown, and gray dolomite and brecciated dolomite containing a few chert fragments and crinoidal limestone fragments near the base and stromatoporoid fragments near the top.

Deiss tentatively suggested that upper Devonian strata 425 feet thick are missing in northwest Montana through erosion or nondeposition, an erosional disconformity separating Devonian from Mississippian beds. Sloss and Laird expressed the opinion that there was only slight pre-Mississippian emergence and almost uninterrupted deposition from Devonian into Mississippian time. They assigned the evaporite-solution breccias, believed equivalent to Deiss' Silvertip breccia-conglomerate, a late Devonian age and believed that Deiss misinterpreted the age of the Silvertip unit when he assigned it to basal Mississippian.

Mississippian

Mississippian rocks are generally present as erosional remnants capping peaks and higher elevations within the Swan Lake NE and Silvertip map areas east of the South Fork. Mississippian strata crop out on Spotted Bear Mountain, Lone Butte, Pentagon and Table Mountains, and opposite Wall Creek adjacent to the east side of Spotted Bear River. Within Swan Lake quadrangle, strata of probable Mississippian age crop out east of Beacon Mountain near the head of Twin Creek.

Deiss, in a preliminary subdivision of Mississippian rocks, separated them into five members equivalent to the Madison Limestone, but later proposed a new name, Hannan Limestone (1943a, p. 229) from a type section in Hannan Gulch within the Sawtooth Range in the Saypo quadrangle. He believed that most of the Mississippian limestone in the Saypo quadrangle was equivalent to the Madison Limestone but that upper beds contained Meramec and Chester species, indicating a late Mississippian age.

In 1962, Mudge, Sando, and Dutro published stratigraphic and paleontological studies of Mississippian rocks in the southern Sawtooth Range within the Sun River Canyon area. Their studies confirmed the Meramec age of the upper part of the Mississippian sequence, but they stated that Chester equivalents are absent (Mudge and others, 1962, p. 2004). They recognized the Mississippian rocks of the Saypo area as equivalent to the Madison Group and subdivided them into two new formations--the Allan Mountain Limestone as the lower formation, which on the basis of faunal zones is tentatively believed to be the same age as the Lodgepole Limestone of southwestern Montana, and the Castle Reef Dolomite, approximately the same age as the Mission Canyon Limestone. The lower formation is divided into three unnamed members, the upper formation into an unnamed lower member plus the redefined Sun River Member. They suggested the name Hannan Limestone be abondoned. These revisions of nomenclature postdate Deiss' mapping in the Silvertip quadrangle, and a study of the type section of the Allan Mountain Limestone and Castle Reef

Dolomite to permit revision of Deiss' mapping of Mississippian outcrop areas was not possible in the time alloted for reconnaissance mapping for this report. Therefore, the name Hannan Limestone was retained for Mississippian rocks in the Silvertip quadrangle, although it was realized that in future work, nomenclature for the Mississippian rocks should conform to that proposed by Mudge and associates.

Hannan Limestone.--In preliminary work the Hannan Limestone was subdivided by Deiss in ascending order into the Silvertip Conglomerate, Saypo Limestone, Dean Lake Chert, Rooney Chert, and Monitor Limestone. Sloss and Laird (1945) separated the Mississippian units by letter and number, which in ascending order are MC, MB, and MA, Unit MA being present only in the Sawtooth Range and farther east; farther west it has been removed by erosion. Unit MC and the lower part of MB (MB_2) are the equivalents of Mudge's Allan Mountain Limestone. The upper part of Unit MB (MB_1) and MA are equivalent to the Castle Reef Dolomite (Mudge and others, 1962, p. 2009-2017).

Thickness of the Hannan Limestone, which for this report includes the basal breccia-conglomerate, ranges from about 790 to 840 feet. On Spotted Bear Mountain, Deiss (1933, p. 44) measured a thickness of 420 feet for the formation, but at this location lower Mississippian strata of undetermined thickness are missing. Sloss and Laird's (1945) Spotted Bear section shows Unit MB in fault contact with DA_1 (Deiss' breccia-conglomerate), and Unit MC missing. Thicknesses of 1,230 to 1,700 feet for Mississippian rocks have been recorded by Sloss and Laird (1945) near Bigson Reservoir and Allan Mountain in the Saypo quadrangle.

The basal Mississippian deposit is a breccia-conglomerate. A thickness of 23 feet is exposed on Spotted Bear Mountain, and 30 to 35 feet near the head of Twin Creek. From Pentagon Mountain south to Lone Butte the breccia-conglomerate thickens from 40 feet to 140 feet.

The brecciated and conglomeritic material is composed of angular to subrounded pebbles to boulders of gray and brown fetid limestone in a matrix of crystalline gray limestone weathering white gray. In the southwest Saypo quadrangle Deiss (1943a, p. 228) mapped a 3- to 7-foot intraformational breccia, which he correlates with this breccia-conglomerate.

Above the breccia is fine-grained argillaceous limestone and thicker-bedded and interbedded white argillaceous limestone, overlain by thick-bedded, gray-weathering, gray crinoidal limestone and chocolate-colored crinoidal limestone. In upper Twin Creek, light-brown-gray thin-bedded limestone above the breccia is interbedded with 2-inch chert beds. The limestone weathers light gray and the chert weathers yellow orange to gray pink. Here the unit is in part very fossiliferous, almost a crinoidal limestone, containing crinoid stems, horn corals, echinoid spines, and bryozoa. These beds above the breccia are probably equivalent to Deiss' Saypo Limestone and Dean Lake Chert and to part or all of Sloss and Laird's Unit MC. At Lone Butte and Pentagon Peak this part of the section represents 72 to 140 feet of the Hannan Limestone.

The overlying beds, typically exposed at Pentagon and Lone Butte peaks, but possibly absent north of these locations, are persistent intercalated zones of black to dark-gray chert in thin-bedded blackish-gray limestone and bluish-gray limestone containing crinoid stems and braciopods. This part of the Mississippian is correlative with Deiss' Dean Lake Chert and roughly equivalent to Sloss and Laird's (1945) Unit MC. About 50 feet of section is represented by these dominantly cherty beds.

Overlying the limestone containing intercalated chert is massive chert-bearing coarsely crystalline white and cream-colored limestone interbedded with calcareous buff shale. Corals, brachiopods, and bryozoa are distributed throughout, but are more numerous in the lower and central parts of this middle section of the Hannan Limestone. This part of the formation is represented by about 550 feet of the section on Pentagon Mountain and 578 feet at Lone Butte. Deiss (1933, p. 47) assigned these strata to the Rooney Chert, which according to Sloss and Laird is approximately the same as their Unit MB.

Sloss and Laird (1945) describe Unit MC as conformably overlying Devonian strata and as thin-bedded dense black argillaceous limestone interbedded with gray or black calcareous shale and considerable black chert. In many places the basal few feet contains prominent crinoid-fragmental limestone and black to dark-brown shale or carbonaceous platy limestone, the carbonaceous material being nonpersistent and occurring near the base.

Unit MB is conformable and transitional with Unit MC. The lower part of the unit is brown to dark-gray well-bedded dense fragmental limestone separated by thin zones of shaly limestone or calcareous shale. Gray chert is present in the dense limestone. The upper part is light-gray, white, brown, and buff coarse fragmental limestone, containing a few beds of gray or brown sparse fragmental limestone, also some zones of abundant gray and white chert. The unit is fossiliferous, bearing both brachiopods and corals. The feature distinguishing Unit MC from MB is the thicker-bedded dense limestone at the base of Unit MB contrasting with the thinner-bedded argillaceous limestone at the top of Unit MC. In subsurface, occasional beds of fragmental limestone in the upper unit differentiate it from the lower unit.

Sloss and Laird's Unit MA occurs only as far west as the Sawtooth Range and is missing through erosion in the Silvertip and Swan Lake quadrangles.

MESOZOIC

Cretaceous

Kootenai Formation.--An undetermined thickness of an incomplete section of Kootenai beds (Lower Cretaceous) crops out in the northeast corner of the Silvertip quadrangle where Kootenai strata are in fault contact with Miller Peak Argillite of the Missoula Group.

The Kootenai Formation was named by Dawson (1885), and the lithologic equivalents of Dawson's Kootenai Formation were mapped by Deiss in the southwest and northwest parts of the Saypo quadrangle, where he estimated a probable thickness of 900 feet in the southwest Saypo area. In the plains area east of the mountains, a thickness of 1,100 feet was measured and for the central Sawtooth Range a probable maximum thickness of 1,500 feet (Deiss, 1943b, p. 1143) was recorded.

Basal Kootenai beds include interbedded blackish-gray micaceous and arenaceous shale and tan, green-gray, red, and red-purple sandstone, overlain by red and green-gray argillaceous and arenaceous fissile shale. The upper half of the formation includes some zones of limonitic and calcareous sandstone and gray gastropod-bearing limestone.

CENOZOIC

Tertiary

Within the map areas Tertiary rocks crop out in a 125-foot vertical bluff on the east bank of the South Fork about 2 miles northwest of Spotted Bear. These poorly consolidated clastic rocks, striking westnorthwest and dipping north, may be the equivalents of the Kishenehn Formation, which underlies most of the valley of the North Fork Flathead River north of Glacier View Mountain.

The continental deposits weather dark gray and are composed of poorly consolidated thick-bedded coarse conglomerate of subrounded cobbles to boulders and some lenticular conglomerate zones of mixed cobbles and coarse-grained sandstone. The beds are overlapped by glacial gravels at the north and terminate against a fault at the south.

Quaternary

Glacial deposits.--Within the map areas, all glacial deposits are attributed to stages of Wisconsin glaciation, including ground moraine and outwash deposits in addition to terminal and recessional moraines bordering some lakes in the region. Glaciofluvial gravels were not distinguished from glacial deposits in the areas, and on Plate 3 glacial deposits and alluvium were mapped as one unit. On Plates 1 and 2, glacial deposits, lacustrine silts, and recent alluvium were each mapped separately.

While drilling for water at the Bill Adams ranch near Proctor, in sec. 30, T. 25 N., R. 21 W., drillers penetrated 300 feet of glacial gravel and sand and 28 feet of fine light-gray silt or volcanic ash(?) before reaching water.

Recent alluvium.--Bordering most rivers and streams are unconsolidated deposits of gravel, sand, and silt mapped as Recent alluvium. These deposits are generally narrow and thin. Where cut banks expose the base, the gravel and sand overlie glacial drift or lacustrine silt.

Flood-plain deposits of fairly recent origin conspicuously border Spotted Bear River from its mouth to a point several miles above Limestone Cabin. Meanders have reworked the flood-plain deposits in recent years, the river carrying some of the sand and gravel to the South Fork.

Along the South Fork are deposits that resulted from tributary streams dropping detritus where stream velocities are reduced as the streams enter the more mature valley. Along some sections of the South Fork, however, the river is actively cutting into bedrock, establishing deep rock-walled gorges. One such gorge extends from the Meadow Creek Cabin pack bridge downstream for a considerable distance.

IGNEOUS ROCKS

Sparse igneous rocks of dioritic or gabbroic composition intrude Belt sedimentary rocks in the form of narrow and moderate sized sills and small irregular masses. These igneous rocks were mapped in Ravalli sedimentary rocks in the Elmo quadrangle, Salish Mountains, and in Missoula undifferentiated on the eastern slope of the Swan Range.

In the Libby quadrangle, Gibson (1948) described similar rocks as metadiorite, but Ross (1959), on the basis of residual pyroxene and abundant calcic plagioclase within intrusive rocks in Glacier National Park, believed that the composition of intrusive rocks in the Flathead region is closer to gabbro than to diorite. Because of sparse occurrence of these igneous rocks in the map area, because of lack of petrographic data for a more precise identification, and because of their similarity in color, texture, and apparent composition to metadiorite intrusive rocks in Lincoln County and western Flathead County, the rocks were mapped as metadiorite.

Ross (1959, p. 56) described intrusive rocks as composed mainly of titaniferous augite essentially altered to hornblende, and plagioclase ranging from about labradorite to oligoclase in composition. Some separate hornblende is probably of primary origin. Additionally, potash feldspar, micropegmatitic intergrowths of quartz and alkalic feldspar, and small amounts of quartz, apatite, and iron oxides are present. Alteration minerals--sericite, chlorite, calcite, and kaolin--obscure texture and compositional relations.

A small irregular body intruded into Ravalli sedimentary rocks is exposed on a ridge line near the West Fork Dayton Creek in the NW$\frac{1}{4}$ sec. 5, T. 25 N., R. 21 W. Two northwest-striking sills in the N$\frac{1}{2}$ sec. 29 and S$\frac{1}{2}$ sec. 20, T. 26 N., R. 22 W., Elmo quadrangle, follow the ridge line for short distances.

On Bunker Creek ridge in sec. 7, T. 24 N., R. 15 W., two northwest-trending sills of moderate thickness intrude Missoula Group sedimentary rocks. Another sill, composed mainly of hornblende, plagioclase, and quartz, is exposed in Bunker Creek in sec. 27, T. 24 N., R. 15 W.

To the south, in unsurveyed sec. 22 and 29, T. 23 N., R. 15 W., two metadiorite sills, one about 50 feet and the other about 200 feet thick, crop out on a ridge line between Gorge and Cannon Creeks. Another sill about 150 feet thick crops out on the north slope of Gorge Creek in the E$\frac{1}{2}$ of unsurveyed sec. 10, T. 23 N., R. 15 W.

The only igneous rock observed in the Silvertip quadrangle is a large metadiorite sill(?) in Gorge Creek drainage in the SW$\frac{1}{4}$ of unsurveyed sec. 35, T. 24 N., R. 14 W. It intrudes ripple-marked and banded grayish-red quartzite and argillite and pale-green argillite near the middle of the Missoula Group.

STRUCTURAL GEOLOGY

SEDIMENTARY ROCK STRUCTURE

Folding in the map areas trends north to northwesterly paralleling the strike of Belt Series rocks and Paleozoic sedimentary rocks. General inclination of the strata is northeast. Laramide folding produced gentle symmetrical folds in the extreme western and eastern parts of the map area, strata throughout the central portion being even less deformed. Later Laramide faulting locally deformed the strata adjacent to faults and tilted some fault blocks. Laramide deformation west of the Rocky Mountain Trench and extending to the Idaho-Montana border produced a greater number of complex folds in strata of the Belt Series than did diastrophic forces east of the Trench; this may indicate that compressive forces in the eastern area were relieved to large extent by the Lewis overthrust and other thrust faults adjacent to the Great Plains.

A gentle north-plunging symmetrical anticline extends northwestward from Proctor through Lake Mary Ronan across the Flathead Lake and Elmo quadrangles. Its axis is breached near Chief Cliff, about 2 miles south of Proctor. A discontinuous syncline west of Lake Mary Ronan parallels the west limb of the anticline. The east limb dips beneath Flathead Lake and the Mission Range.

The Mission Range is a northward-tilted block bounded by faults along the east shore of Flathead Lake and the west shore of Swan Lake. Beneath Swan Lake the strata are horizontal, producing a structural terrace broken by faults where beds again assume easterly dips.

A broad symmetrical syncline, the Silvertip syncline, was described by Chapman (1900, p. 155) in a report on a reconnaissance in the Lewis and Clark timber reserve (now part of the Flathead National Forest). The synclinal axis conforms to position and trend of the White River and Silvertip Creek. The fold extends from the south map border to a point beyond Whitcomb Peak, a distance of 28 miles.

A northwest-plunging syncline, its east limb faulted, trends northwest for an undetermined distance from Black Bear Creek.

Strong fracture cleavage striking north to N. 25° W. and dipping 50° to 75° W. is particularly well developed along the northwest-trending divide at the head of Hilburn Creek and its tributaries in the southwest corner of the Elmo quadrangle. Fracture cleavage nearly obliterates bedding along the divide and on its flanks. This intense fracture cleavage may be related to tectonic forces acting at the time of intrusion of dikes and plugs and during emplacement of volcanic rocks in the Hog Heaven district, which borders the western boundary of the Elmo quadrangle.

FAULTS

Description of Faults

Principal faults parallel north-trending valleys; major fault structures border Swan River, South Fork Flathead River, and the east side of the Rocky Mountain Trench. From the Middle Fork Flathead River in the Marias Pass quadrangle, the Lewis overthrust enters the Silvertip NE quadrangle for a distance of 4 miles.

A major tectonic break paralleling the east side of the trench has been inferred to extend from Yellow Bay north to Bigfork, where it disappears beneath Recent alluvium. Evidence for the fault is the stratigraphic relationship between east-dipping Piegan units on the west shore of Flathead Lake, which, if projected eastward, would underlie Appekunny (older) beds.

At Yellow Bay an outcrop of central Piegan strata (pyritic molar-tooth yellow-gray limestone) lies west of the inferred fault position, whereas strata in the lower part of the Ravalli Group crop out east of the fault. The fault is believed to be a high-angle, west-dipping normal fault on which stratigraphic displacement amounts to at least 4,500 feet but probably does not exceed 10,000 feet. The entire Grinnell and lower Piegan units plus an undetermined amount of upper Appekunny and lower central Piegan beds have been offset by the structure.

Swan Valley is bordered by normal faults east and west of Swan Lake. Along the west shore a high-angle normal fault has a stratigraphic throw amounting to about 2,100 feet. The east border fault has a greater but undetermined displacement. Along Sixmile Creek, northeast of Swan Lake, Grinnell rocks west of the fault are in contact with older Appekunny rocks east of the fault. A mile farther southeast, horizontal P_1 strata (section A-A, Pl. 2) are in fault contact with Grinnell beds. This fault is believed to be the south extension of the Swan fault mapped by Clapp (1932) and by Smith and Barnes in the Whitefish Range (Johns and others, 1963).

A north-striking west-dipping normal fault northwest of Hall Creek has repeated Grinnell strata.

Deiss mapped a major fault in the valley of the South Fork trending about N. 20° W., portions of which are concealed by alluvium and drift. The fault trace from the Flathead County line north to Spotted Bear River follows the base of the west flank of the Flathead Range. Topographic expression is apparent where the fault trace crosses near-perpendicular ridges and in a swale between Black Bear Creek and Mid Creek.

Between Blackbear Guard Station and Meadow Creek Cabin the fault splits into two segments enclosing a lenticular body of Devonian strata in fault contact with Cambrian on the west and Missoula Group units on the east. The fault is believed to be a high-angle fault whose west side moved down relative to the east side. From the county line to Blackbear the stratigraphic throw is large, as strata in the lower part of the Miller Peak are in fault contact with upper Middle Cambrian members. The stratigraphic displacement decreases northward.

Another fault segment extends southeast from the mouth of Cedar Creek and passes west of Meadow Mountain and Black Bear Mountain to terminate near the junction of Rambler and Black Bear Creeks. Along its southwest trace, lower middle Missoula strata are in fault contact with lower Middle Cambrian rocks. The west side of the structure moved up relative to the east side.

From the Rambler Creek-Bear Creek junction a normal fault, downthrown on the west, extends northwestward to the northwest corner of the quadrangle; Devonian rocks are in fault contact with undifferentiated Missoula beds. The fault trace is near the synclinal axis of a fold, and along strike has displaced the east limb.

Deiss traced a west-dipping overthrust fault from the Continental Divide along Spotted Bear River, up Pentagon Creek, past Pot Mountain, across Argosy Creek, into the Marias Pass quadrangle west of longitude 113°10'. From Pentagon Mountain to Three Sisters Peak, strata of the Missoula Group are thrust over Mississippian and Devonian rocks. The attitude of this thrust is believed to be somewhat steeper than that of the Lewis overthrust, which is about 7 miles northeast.

In the northeast corner of the Silvertip NE quadrangle, the Lewis overthrust was traced for a distance of 4 miles. Ross (1959, p. 76) described the overthrust in the Flathead region as striking N. 30° W. and having maximum dip of 50° SW. The overthrust in the map area trends about north-south. Missoula units override Kootenai (Cretaceous) sedimentary rocks.

A fault striking N. 60° W. is exposed on Spotted Bear road 1 mile northeast of Spotted Bear bridge. The southwest side moved up relative to the northeast side, and drag folding is observable adjacent to the fault.

North of Whitcomb Peak a fault striking N. 75° W. crosses the Silvertip syncline. Movement is up on the north side relative to the south side.

Near Angel Point, on the west shore of Flathead Lake, an east-west fault dipping south was mapped from aerial photographs. The displacement seems to be small.

Summary of Faulting

Large northwest high-angle faults about parallel to regional strike of Belt Series rocks and Paleozoic sedimentary rocks mark the east side of the Rocky Mountain Trench, the Swan Valley, and the South Fork Flathead Valley. The faults are believed to be normal faults dipping westward, but the fault planes are nowhere exposed, and segments of the faults are covered by drift and alluvium. It is possible that these structures could be reverse faults dipping at high angles to the east, as some workers have suggested (Clapp, 1932; Shepard, 1922). It is also conceivable that near-vertical structures can change attitude along strike from place to place, but in the opinion of the writer the faults are normal faults creating grabens between ranges.

The Lewis overthrust and a subsidiary thrust dip westward and strike north to northwest. Along the trace of the Lewis overthrust, rocks in the lower part of the Missoula Group are thrust over Kootenai beds. Along the fault trace of the subsidiary structure, strata of the Missoula Group are thrust over Devonian and Mississippian beds.

Two vertical(?) westnorthwest-trending faults, the southwest sides of which moved up relative to their northeast sides, displace the fold axis of the Silvertip syncline near Whitcomb Peak and downdropped a small remnant of Tertiary clastic rocks that crop out 2 miles northwest of Spotted Bear Ranger Station.

ORE DEPOSITS

Production from prospects within the mapped quadrangles has been insignificant, although numerous properties within rocks of the Ravalli Group are associated with fissure-filled veins. Development work has been of a cursory nature except for a few adits and shafts that have explored more promising structures for considerable distances such as at the Jumbo mine northeast of Lake Mary Ronan.

The prospects examined in the map area were discovered and developed in the interval between 1900 and 1930 except for slight additional work after 1930. Some recent activity near the head of Truman Creek was stimulated when, during road construction, sparse copper-bearing quartz veins were discovered.

LEAD-SILVER AND COPPER-BEARING QUARTZ VEINS

Sparse lead, silver, and copper minerals occur sporadically in small fissure-filled veins within the Elmo quadrangle. They seem to lack any definite relationships to igneous rocks. The nearest large body of igneous rock is 8 to 10 miles west of the quadrangle, in the Hog Heaven district of the Horse Plains quadrangle. A small stocklike metadiorite outcrop was examined in sec. 5, T. 25 N., R. 21 W. Most of the fissure veins trend slightly north or south of east or else northwestward, and they parallel the faults in the area.

All samples were assayed by Frank P. Jones, Bureau analyst.

DESCRIPTION OF MINING PROPERTIES, ELMO, SWAN LAKE, AND NYACK QUADRANGLES

Jumbo Mine

The Jumbo mine, according to C. B. (Bill) Adams, of Proctor, was discovered prior to 1916 and was being developed when he visited the property in 1918. After an inactive period of several years, the property was reopened in 1925-26, when several men were employed sinking a winze on the vein below the adit level, reportedly to a depth of 200 feet. The property has been idle since 1926, according to Adams.

The portal of the adit is near the southwest corner of the NW$\frac{1}{4}$ sec. 6, T. 25 N., R. 21 W., on a tributary of the North Fork Dayton Creek. At the time of the writer's visit, the adit, trending N. 30° W., was caved at the portal, the two cabins were collapsed, and the compressor building had been dismantled. A dump containing about 50,000 tons of waste rock indicates considerable development work.

Vuggy quartz is scattered over parts of the dump, and a small stockpile of white vuggy quartz containing galena and sparse malachite and azurite was sampled selectively for assaying. One sample contained 10.20 percent lead, 1.40 ounces silver, and 0.003 ounce gold a ton. Another sample of vein material from the dump contained very sparse amounts of gold, silver, and copper. At the time of Adams' visit in 1925, about 150 pounds of galena ore was stockpiled next to the compressor building.

On a ridge a quarter of a mile west of the Jumbo adit is an outcropping quartz vein striking N. 85° W. The vein was developed by a shaft (now caved), a 40-foot trench, and two shallow pits. Brecciated white quartz stained with copper carbonate is abundant on the dump, and 15 to 20 tons of white vuggy copper-stained quartz had been stockpiled. Some chalcopyrite accompanies the quartz. The vein width could not be determined, as the contact with the sedimentary rocks is covered. From the size of quartz boulders in the stockpile, the width of the vein is estimated to exceed 2 feet. The shaft and east-west trench could be on the apex of the Jumbo vein.

A selected sample from the stockpile containing azurite- and malachite-bearing quartz assayed 1.13 percent copper, 0.006 ounce gold, and 0.05 ounce silver a ton.

The Jumbo property and the west vein extension(?) are in Ravalli sedimentary rocks that strike northwest and dip east.

Big Four Prospect

The Big Four is in the SE$\frac{1}{4}$ sec. 31, T. 26 N., R. 21 W., on the North Fork Dayton Creek. The claim was located prior to 1910, and is now held by Bill and Matt Wilhelm, sons of the original locator.

A crosscut adit striking N. 35° E. intersects a 12$\frac{1}{2}$-inch vein at a distance of 245 feet from the portal. The adit continues beyond the vein in Ravalli rocks on a northeast bearing for an additional 115 feet. Total adit length amounts to 360 feet.

A 75-foot southeast-bearing drift exposes the vein striking N. 75° to 80° W. and dipping 80° to 85° S. Vein material consists of white vuggy quartz and abundant iron oxides. The vein narrows to a few inches at the southeast end of the drift. Workings are in light-gray quartzite and medium-light-gray argillite of the Ravalli Group, which strike N. 15° W. and dip 30° E.

A channel sample normal to the vein, here 6 inches wide, was collected 8 feet east of the adit-drift intersection. The sample assayed 0.11 percent copper, 0.20 ounce silver, and 0.001 ounce gold a ton.

Mosher Prospect

The Mosher prospect was located about 1910 by Joe Mosher who, according to Bill Adams, was grubstaked by Clarence E. Proctor. Adams reports that $40,000 was spent developing the prospect. The property is in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 21, T. 25 N., R. 21 W., on grazing and timber land owned by Bill Adams.

Development amounts to a 6 x 8 x 25-foot shaft, now inaccessible, on the top of a ridge, and southeast of the shaft a 330-foot accessible adit striking N. 78° W., with which Mosher attempted to intercept the vein at a lower elevation. Four trenches between the shaft and the tunnel are now filled with debris.

A 10- to 12-inch vein of white massive quartz bearing sparse azurite and malachite, exposed at the collar of the shaft, strikes N. 80° W. and dips 80° S.

In the tunnel a few 1/32- to 1/16-inch veinlets containing chalcopyrite and some tenorite are intercepted 100 to 120 feet from the portal. The veinlets parallel the adit trend. Two northwest-striking faults, both containing several inches of gouge, are intercepted midway in the tunnel. The adit parallels the strike of the vein exposed in the shaft; the vein may lie either north or south of the tunnel.

The shaft and tunnel are in light-gray thin- and medium-bedded argillaceous quartzite and argillite of the Ravalli Group, which here strike N. 15° W. and dip 26° E.

The quartz vein was not sampled.

Unawah Prospect

The Unawah prospect is located in unsurveyed sec. 13, T. 28 N., R. 17 W., on the north side of Unawah Creek adjacent to Felix basin. The prospect is outside the map area but within the Nyack quadrangle, the aerial geology of which was mapped by Ross (1959). The workings are east of Hungry Horse Reservoir and 21 airline miles northwest of Spotted Bear. The property is developed by an 8-foot open cut and a 30-foot adit.

A 2- to 5-inch quartz vein containing malachite, chalcocite, and iron oxides in blebs and vugs strikes N. 30° W. and dips 55° S. Paralleling the right wall of the adit is a premineral(?) fault, indicated by 2 inches of gouge and talc and as much as 12 inches of breccia, striking N. 30° W. and dipping 87° S. Iron oxides, silica, and malachite locally replace argillite along bedding on the west side of the adit.

Country rock is reddish-purple argillite of the Grinnell Formation (Ravalli Group), which at the prospect strikes N. 10° to 20° W. and dips 33° to 65° NE. North of the property the attitude of the formation is N. 10° W., 10° NE.

A selected dump sample assayed 1.33 percent copper, and 0.35 ounce silver a ton.

Other Prospects

Mining activity on the South Fork of Logan Creek, north of the map area in the Nyack quadrangle, 15 airline miles from Spotted Bear, is believed to have commenced prior to 1896 with the location of a quartz claim named Bell of the West. The claim, 4 miles east of Hungry Horse Reservoir, was later relocated by William Corran and J. N. Orgard. In 1896 these locators patented the Little Darling and Jeanette Lodes, Survey No. 5353 and 5354. The claims are presently owned by Virginia and Norman Rousselle of Kalispell.

The patented claims were reported to have been developed by an incline shaft and adit, now caved, on the north side of Logan Creek. These workings were not found by the writer. An adit was reported (personal communication, Ben Trosper) to enter the hill on the south side of the South Fork Logan Creek.

An open cut adjacent to U. S. Forest Service Trail 62 in the W$\frac{1}{2}$ unsurveyed sec. 5, T. 27 N., R. 16 W., exposes a 3-inch vertical quartz vein striking N. 84° E. The vein contains milky quartz and small masses of chalcocite and hematite. The cut is in the Grinnell Formation where bedding strikes N. 5° W. and dips 10° E.

At the head of Silver basin (upper South Fork Logan Creek) between Baptiste Lookout and Mount Baptiste, a 20-foot timbered shaft was sunk in the basal unit of the Piegan Group. No ore mineral was found on the dump, and no veins were visible from the collar of the inaccessible shaft.

On Truman Creek-Blacktail Mountain road 0.4 mile south of Kerr Mountain in the SE$\frac{1}{4}$ sec. 24, T. 26 N., R. 22 W., a 4 x 6-foot pit at the base of a cliff exposes a 17-inch quartz vein striking east and dipping 74° S. The vein has hematite-filled vugs in massive white quartz. Specular hematite is found as unaltered masses in quartz. A fault indicated by 2 inches of shattered rock and gouge parallels the hanging wall of the vein, which is in purple-gray finely banded quartzite of the Ravalli Group striking N. 47° W. and dipping 25° NE.

Three intersecting(?) quartz veins are exposed in a road-cut at the head of Truman Creek near the center of the E$\frac{1}{2}$ sec. 26, T. 26 N., R. 22 W. Small limonite-filled vugs in shattered quartz were noted in 3$\frac{1}{2}$- and 1$\frac{1}{2}$-inch veins striking northeast and east respectively. White massive vuggy quartz, containing siderite and iron oxides, is poorly exposed in a +6-inch vein believed to strike northwest. Traces of copper and silver are associated with the quartz veins. Two claims, Old Dominion No. 1 and 2, were located by Gary L. Vollmer of Kalispell on October 8, 1960.

In a highway cut near Swan Lake in the SE$\frac{1}{4}$ sec. 4, T. 25 N., R. 18 W., a $\frac{1}{4}$-inch veinlet of powdery malachite follows bedding in Grinnell Argillite. A sample of the mineral zone assayed 1.16 percent copper and 0.55 ounce silver a ton. Locally at other locations east of Swan Lake, malachite was found as blebs commonly surrounding a chalcopyrite nucleus.

A piece of lead-zinc float was reported found in 1926 during trail construction on the Helen Creek trail in the N$\frac{1}{2}$ sec. 33, T. 23 N., R. 13 W., at a point where the trail turns from a northeasterly to a southerly direction. The float may have come from the divide south of Helen Mountain.

U. S. Forest Service personnel report that a sluice box was observed about 1925 near the mouth of Hodag Creek about a mile north of Blackbear Guard Station. The sluices have now disappeared, and no tailings were noted at this location.

Barren quartz veins and veinlets striking about N. 75° W. and dipping 11° NE are exposed by three or more shallow pits on the north slope of Soldier Creek north of Soldier Lake in the NE$\frac{1}{4}$ sec. 32, T. 26 N., R. 16 W.

NONMETALLIC DEPOSITS

Within the Swan Lake and Silvertip quadrangles, nonmetallic deposits are sporadic, sparse to moderate amounts being indicated by surface exposures. An undeveloped barite vein on upper Black Bear Creek in the Flathead Mountains has barite exposed intermittently for a distance of 550 feet. A narrow asphaltite dike crops out along U. S. Forest Service Trail 80, 2 to 2$\frac{1}{2}$ miles north of Black Bear Creek. Erdmann (1944) reports other asphaltite dikes in sec. 3, approximately 1 mile east of this location.

An oil seep has been reported in the E$\frac{1}{2}$ sec. 9, T. 23 N., R. 14 W. This report was not verified, although only cursory searching was done in this area.

Limestone of probable Mississippian age (Hannan Limestone) is present in moderate amounts east of Beacon Mountain, on top of Spotted Bear Mountain north and southeast of Spotted Bear, and in other less accessible locations within the Silvertip quadrangle. All limestone outcrops are difficult of access, and road building to these locations would be costly.

Gravel and sand are present as admixtures in glacial drift or moraine within river valleys and bordering Flathead Lake. Cenozoic lakebed clays of the type occurring in Flathead Valley and the valley of the North Fork Flathead River are only sparingly present in the map areas.

Barite

Barite in a fissure-filling vein deposit crops out adjacent to Forest Service Trail 220 near the head of Black Bear Creek in the Bob Marshall Wilderness Area. The deposit is $2\frac{1}{2}$ airline miles southwest of Silvertip Mountain in the $W\frac{1}{2}$ of unsurveyed sec. 16, T. 23 N., R. 13 W., Flathead County. Two northeast-trending claims, Glacier No. 1 and 2, were staked in May 1957 by Levi A. Gaustad, Melvin W. Myers, and Ben C. Trosper of Kalispell. A pit 13 x 3 x 5 feet and a cut 20 x 6 x 3 feet were dug above and below the trail.

At the upper pit on Glacier No. 1 claim, barite is exposed across a width of 13 feet without revealing the hanging or footwall of the near-vertical vein, which strikes N. 78° E. About 50 feet northeast of the pit the vein is 10 feet wide. It narrows to a 3-foot width 100 feet from the pit and pinches out on surface outcrop at a distance of 135 feet. Southwest of the pit the vein is 11 feet wide where it is crossed by Trail 220. Farther southwest below the trail, the vein is $8\frac{1}{2}$ feet thick in the cut on Glacier No. 2 claim. The vein here strikes N. 60° E. and dips 85° S. Barite is intermittently exposed for a total distance of 550 feet on the surface.

Barite from the property is white to pinkish-white and maroon crystalline and massive material containing specular hematite. Some specimens contain voids previously filled with pyrite. Several precent of strontium is associated with the barite.

Along the footwall of the cut (north side) a $2\frac{1}{2}$-foot breccia zone has broken and angular fragments of barite, chert, and red fissile argillite in a matrix of gouge and crushed rock.

A channel sample normal to the 13-foot vein in the pit contained 57.4 percent barium oxide (BaO) and 30.6 percent sulfate (SO_3).

The deposit is in medium- and light-gray to very light gray, fine- to medium-grained thin-bedded sericitic quartzite interbedded with some gray-red argillite. The bedding attitude is N. 4° E., 49° E. The strata are in the Missoula Group of the Belt Series (Precambrian).

Access to the property is by trail following the north side of Black Bear Creek to the mouth of Rambler Creek, up Black Bear Creek drainage for a short distance, then up and along the north slope of Black Bear Creek Valley to the property. The final 2 miles of trail is steep, includes many switchbacks, and is difficult to travel.

Asphaltite

A 3/4-inch dike of asphaltite is located on the east side of Forest Service Trail 80 along the South Fork Flathead River 2 to 2½ miles north of Black Bear Creek in the S½ unsurveyed sec. 4, T. 23 N., R. 14 W. The dike strikes N. 74° W. and dips 74° S., and consists of a very dark gray to black shalelike rock, which burns on application of heat. The dike is in Devonian light-gray fetid yellow-brown-weathering dolomite, which strikes N. 35° W. and dips 30° E.

Erdmann (1944) reported other dikes near the mouth of Mid Creek in unsurveyed sec. 3, T. 23 N., R. 14 W., in sedimentary rocks of probable Devonian age.

Limestone

Limestone in the Belt Series (Precambrian) was mapped as the middle Piegan unit, correlative with the Siyeh Limestone of the Flathead region. This unit crops out in the south Salish Mountains of the Flathead Lake quadrangle and on the east slope of the Mission Range and west slope of the Swan Range of the Swan Lake quadrangle. Impure limestone and calcareous argillite near the center of the Missoula Group (Cayuse Limestone) crop out on the upper eastern slope of the Swan Range.

Paleozoic Cambrian and Mississippian limestone and Devonian limestone and dolomite are almost confined to the Silvertip quadrangle, although there is a small outcrop in the northeast corner of the Swan Lake quadrangle. Hannan Limestone (Mississippian) is ordinarily restricted to small erosion remnants atop high peaks or ridge lines, most of which are inaccessible.

The Piegan limestone is impure, containing various amounts of silica, magnesia, iron oxides, and other impurities. Cubic crystals of pyrite are a common component in outcrop areas west of the Rocky Mountain Trench but are not as prevalent eastward. In some analyses, the amount of silica equals or is greater than the carbonate content of the rock. Ross (1959, p. 55) gave analyses of two specimens of Siyeh Limestone yielding 36.1 and 17.36 percent calcium oxide, 23.73 and 48.81 percent silica, 4.25 and 7.51 percent alumina, 2.73 and 3.73 percent magnesia, and 1.44 and 1.89 percent combined ferrous and ferric oxides.

Paleozoic limestone beds, almost entirely Cambrian strata, crop out extensively on the east side of the South Fork from Hungry Horse Reservoir south to Bunker Creek, and on both sides of the South Fork from this point to Big Salmon Lake. Paleozoic strata occupy the center and flanks of the Silvertip syncline along White River and Silvertip Creek. These Paleozoic limestone beds are less impure carbonate rock than the limestone in the Siyeh and in the Missoula Group, but are as yet inaccessible except by trail.

Oil and Gas

In central and northwest Montana within the Devonian and Mississippian, petroleum and gas possibilities are probably limited to the petroliferous and brecciated Devonian rocks and brecciated basal Mississippian strata having a primary crystalline porosity that can be developed into effective porosity and permeability. In addition, pre-upper Jurassic erosion and weathering that penetrated Mississippian strata thereby creating porous zones, and association with suitable structure are also factors affecting oil accumulation (Sloss and Laird, 1945).

West of the Continental Divide, however, the brecciated zone in basal Mississippian rocks is thin, and upper Mississippian strata that might have been affected by pre-Jurassic weathering are missing. Oil and gas possibilities in Paleozoic rocks within the map areas are probably poor, because of these factors and because of the shallow depth of burial of favorable reservoir rocks.

GEOCHEMICAL SOIL SAMPLING IN EAST PART OF LIBBY QUADRANGLE

In a two-week geochemical sampling program along the Snowshoe fault vein in June 1964, the Lemaire mercury sensor was used in conjunction with sampling of soil for heavy metals. The area investigated was adjacent to and along the Snowshoe fault in the east half of the Libby quadrangle in Lincoln County, northwest Montana (Fig. 5). The three-man crew consisted of W. M. Sahinen, Pacific Power & Light Co., and W. M. Johns and D. C. Lawson, Montana Bureau of Mines and Geology.

The Lemaire mercury sensor is an instrument used for geochemical prospecting for ore shoots in areas of known mineralization. Certain types of ore deposits are enveloped by a mercury halo, which can be detected and measured by the masking effect of mercury vapor on ultraviolet light. The instrument, designed to measure the concentration of mercury in the soil, was

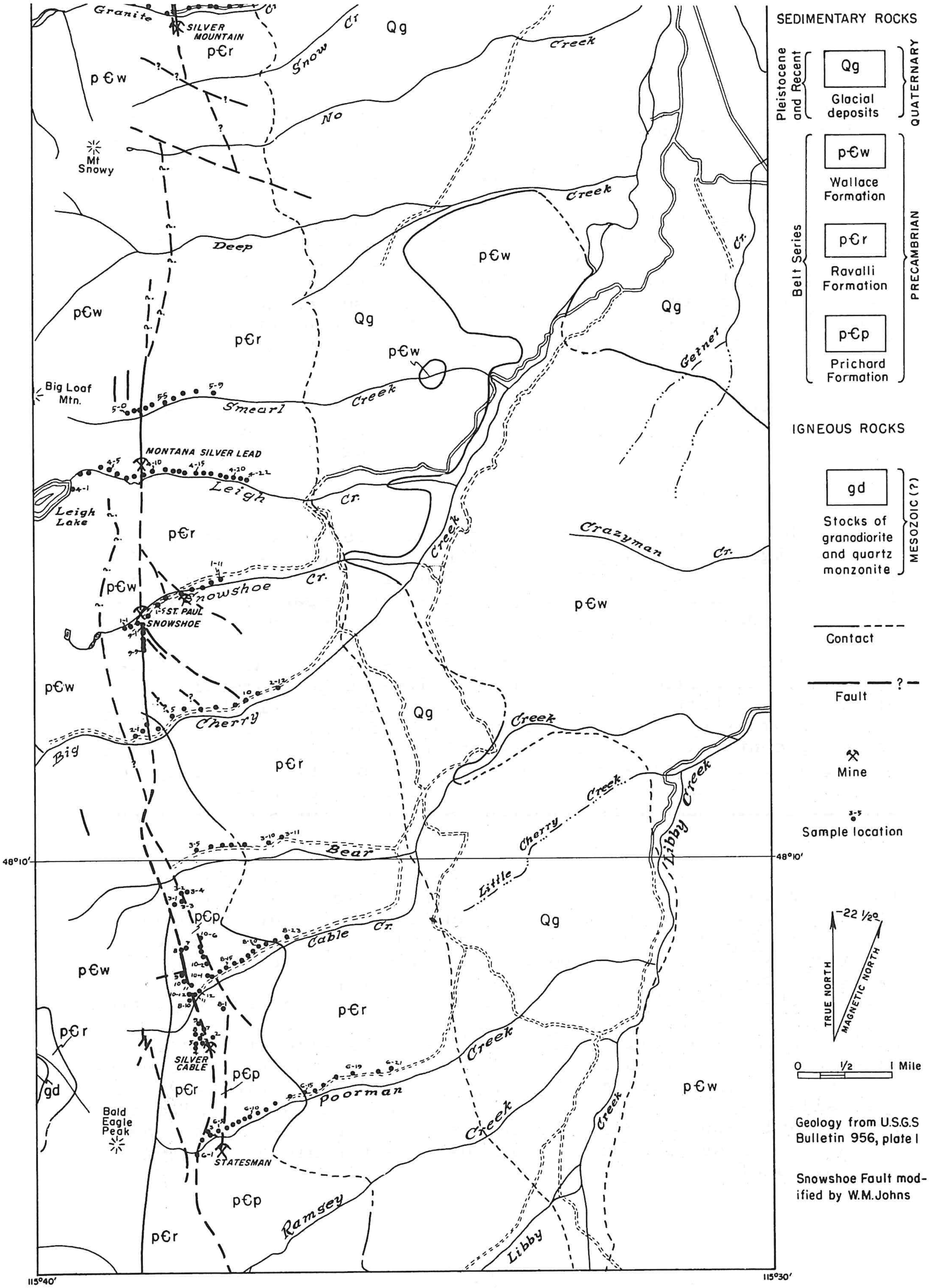

Figure 5.--Plan map of Snowshoe fault showing location of traverses.

operated in conjunction with a standard geochemical method of soil analysis in which the heavy metals, copper, lead, and zinc, are extracted from the soil sample with toluene, and the metal ion concentration is measured colorimetrically with dithizone.

Sampling traverses were located in major drainages trending perpendicular to and crossing the Snowshoe fault, besides two along the Snowshoe fault vein. Individual samples were spaced about 1/10 mile apart. Where possible, samples were taken from the mineralized "C" soil zone, sun dried, screened, and analyzed for mercury and heavy-metal content at base camp. Sampling of snowslide areas was avoided as much as possible to eliminate any contamination.

Altogether, 131 samples were obtained from traverses in Snowshoe, Cable, Cherry, Bear, Smearl, Leigh, Poorman, and Granite Creeks, and from two traverses along the Snowshoe vein, one on the south side of Snowshoe Creek and one on the north side of Cable Creek.

A background count of two for heavy-metal ion concentration and a background reading of $\frac{1}{4}$ to 2 for the sensor was determined from sample results for the area. Anomalous readings exceeding four times background for heavy metals were regarded as significant. Sensor readings greater than 2 may be significant.

Traverses along the Snowshoe vein south of Snowshoe Creek (Fig. 6A) and north of Cable Creek indicated heavy-metal anomalies for both locations. South of Snowshoe Creek, a heavy-metals anomaly built to a maximum (25++) for five stations, then dropped, confirming the presence of the Snowshoe ore body. The strength of the dithizone solution used was sifficient only to determine base metal content to 25; metal ion concentration exceeding this number is reported as + or ++ for samples in which concentrations are abnormally high.

North of Cable Creek, traverses along both the Snowshoe fault and the parallel segment east of the main fault gave anomalous readings, but intensity and continuity of the highs were less than over the Snowshoe ore body. Of particular interest were two highs of 16 and 25+ (stations 10-9 and 10-10) along the Snowshoe fault and below an outcrop of massive siliceous rock. The outcrop continues (stations 10-8 and 10-9) from the Black Bear-Cable ridge south for a distance of about 800 feet. The mass is ellipsoidal and trends parallel to and lies within(?) the fault zone. Drag folding along the fault near the ridgetop indicates movement of the east side up (Prichard) and west side down (Ravalli). Gouge and breccia in a post-mineral 2-foot fault zone borders the east side of the siliceous zone. A sensor reading of 5 at station 10-9 was the highest recorded for any sample.

Where traverses crossed the Snowshoe fault on Snowshoe (Fig. 6C), Cherry (Fig. 6D), and Leigh Creeks (Fig. 7A), soil samples indicated anomalies of nine to ten times background. On Cable Creek (Fig. 6B) at station 8-12 on the fault an anomaly of four times background was recorded, and at station 8-19, which is 0.8 mile east of the Snowshoe fault, an anomaly of eight times background occurs. The anomalous area (8-19R) was resampled, confirming the high. Another anomaly at station 1-7 on Snowshoe Creek (Fig. 6C) is believed to be related to the St. Paul vein crossing(?) the creek at this location.

On Smearl and Granite Creeks where soil traverses crossed the fault, no significant base-metal anomalies were found. Bear Creek traverse was inconclusive, because the fault is probably an additional 275 feet west of Sample 3-1. Higher-than-average sensor readings on fault stations were recorded for Smearl, Poorman (Fig. 7B), and Cable Creeks (Fig. 7C). Sensor readings for the Poorman Creek traverse, excluding those stations on the Snowshoe fault, were higher than those recorded on other drainages. This suggests the possibility of a buried intrusive mass in the area.

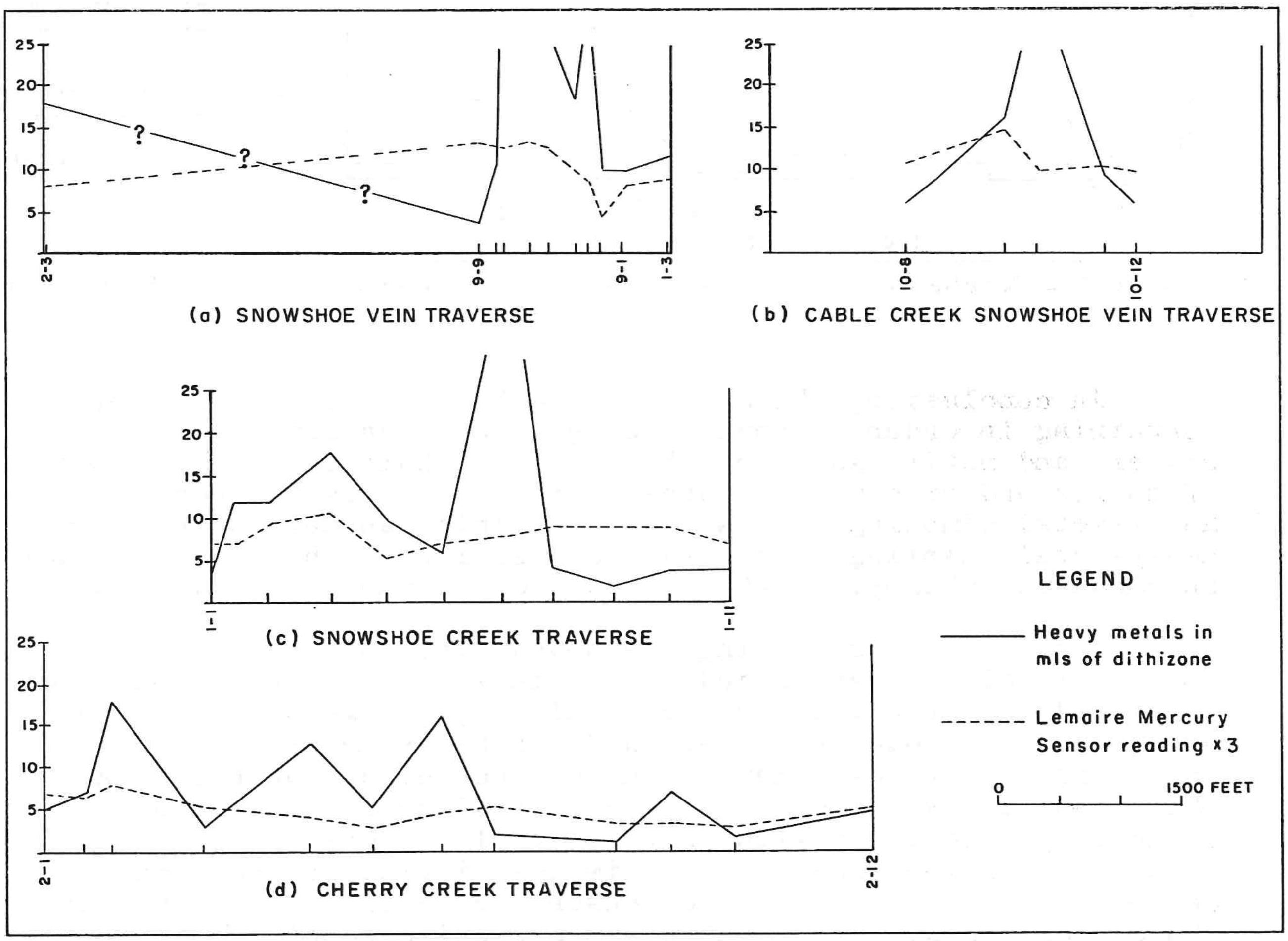

Figure 6.--Geochemical profiles, Snowshoe vein, Cable Creek, Snowshoe Creek, and Cherry Creek traverses.

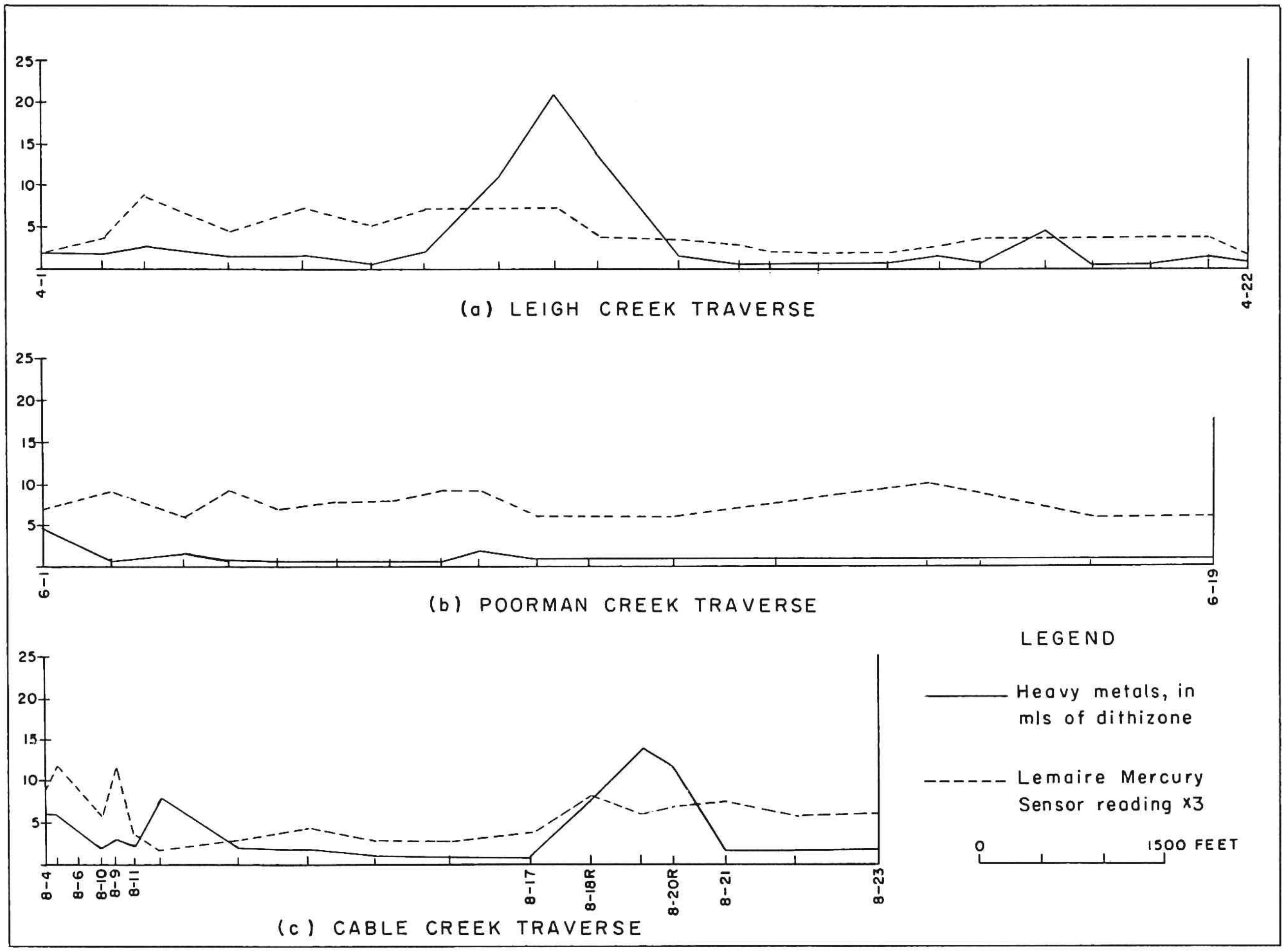

Figure 7.--Geochemical profiles, Leigh Creek, Poorman Creek, and Cable Creek traverses.

In conclusion, the Snowshoe ore body, a fissure-filled vein containing in order of abundance, galena, sphalerite, pyrite, silver, and native gold, pyrrhotite, and chalcopyrite in a gangue of quartz and siderite and other carbonates, was defined by heavy-metal sampling that showed a definite anomaly over the ore. Heavy-metal sampling confirmed the position of the Snowshoe fault on Snowshoe, Cherry, Leigh, Cable, and Poorman Creek(?) traverses.

Mercury sensor readings recorded over the Snowshoe vein and Cable vein traverses and at the intersection of the Snowshoe fault and east-flowing drainages, although anomalous, were not of the order of magnitude recorded for heavy metals, and were more difficult to correlate with surface geology of the area. This might be explained by the very samll or insignificant amounts of mercury associated with Snowshoe fault mineralization. If in other mineralized areas mercury is associated with base metals in greater concentration, the sensor should give higher readings above background, giving better interpretive results. The presence of sulfur in the soil sample could affect the sensor and give a higher than normal reading.

Sun drying the samples, rather than application of artificial heat such as oven drying whereby higher temperatures are produced, is believed to be the better method for reducing soil-sample moisture before sensor analysis. Loss of mercury may result on application of heat.

A P P E N D I X

Snowshoe Creek Traverse

Sample no.	Location	Description	Mercury sensor	Heavy metals
1-1	420 ft. W. old millsite	Mixed A[1], C[2] zone	2.75	2
1-2	60 ft. W. old millsite	Mixed A, C, old landslide	2.75	12
1-3	Snowshoe vein, S. end road	C zone	3.0	12
1-4	.10 mi. E. lower portal	C zone	3.5	18
1-5	.20 mi. E. lower portal	C zone	1.75	10
1-6	.30 mi. E. lower portal	C zone	2.25	6
1-7	.40 mi. E. lower portal	C zone, St. Paul vein (?)	2.50	25+
1-8	.50 mi. E. lower portal	Mixed A, C, below adit	3.0	4
1-9	.60 mi. E. lower portal	C zone	3.0	2
1-10	.70 mi. E. lower portal	C zone	2.75	4
1-11	.80 mi. E. lower portal	C zone	2.25	4

Cherry Creek Traverse

Sample no.	Location	Description	Mercury sensor	Heavy metals
2-1	Snag S. of falls	Poorly developed C zone	2.25	5
2-2	Opposite falls	Poorly developed C zone	2.2	7
2-3	In small clump pines	Poorly developed C zone	2.6	18
2-4	In timber, S. edge avalanche	Good C zone	1.75	3
2-5	End trail, N. of avalanche area	Good C zone	1.5	13
2-6	Cabin at end of road	Good C zone	0.9	5
2-7	.15 mi. E. 2-6	Good C zone	1.5	16
2-8	.80 mi. E. 2-7	Good C zone	1.8	2
2-9	.25 mi. E. 2-8	Good C zone	1.2	1
2-10	.10 mi. E. 2-9	Good C zone	1.2	7
2-11	.10 mi. E. 2-10	Good C zone/charcoal[3]	1.0	2
2-12	.25 mi. E. 2-11 (adit is .25 mi. E. 2-12)	Good C zone/charcoal	1.85	5

Bear Creek Traverse

Sample no.	Location	Description	Mercury sensor	Heavy metals
3-1	275 ft. W. Snowshoe fault	Wet brown soil	3.3	5
3-2	West of Snowshoe fault	Poorly developed/rock	4.0	7
3-3	On fault segment(?)	Poorly developed/rock	3.8	2

3-4	On fault segment(?)	Mixed A and C	3.3	3
3-5	.15 mi. E. 3-4	Mixed A and C	2.5	2
3-6	.10 mi. E. 3-5	Mixed A and C	2.5	2
3-7	.10 mi. E. 3-6	Mixed A and C	1.7	6
3-8	.10 mi. E. 3-7	Mixed A and C	1.5	1
3-9	.10 mi. E. 3-8	Mixed A and C	2.2	3
3-10	.25 mi. E. 3-9	Mixed A and C	2.3	5
3-11	.10 mi. E. 3-10	Mixed A and C	2.1	2
3-12	.12 mi. E. 3-11	Mixed A and C gravel zones	1.8	5
3-13	.20 mi. E. 3-12	Mixed A and C gravel zones	0.8	4
3-14	.12 mi. E. 3-13	Mixed A and C gravel zones	2.4	4

Leigh Creek Traverse

4-1	W. of fault	Poor C zone, on bedrock	0.5	2
4-2	W. of fault	Poor C zone, on bedrock	1.25	2
4-3	W. of fault	Poor C zone, on bedrock	2.85	3
4-4	W. of fault	Mixed A and C, on bedrock	1.50	2
4-5	W. of fault	C zone with rock	2.25	2
4-6	W. of fault	C zone with rock	2.0	1
4-7	W. of fault	Good C zone	2.25	2
4-8	On fault(?)	A, C, and rock	2.25	11
4-9	On fault(?)	A, C, and rock	2.25	21
4-10	E. of fault	C and rock	1.50	14
4-11	0 mi. (commence road traverse)	C and rock	1.25	2
4-12	.10 mi. E. 4-11	C and rock	1.0	1
4-13	.10 mi. E. 4-12	C and rock	0.75	1
4-14	.12 mi. E. 4-13	Poor A and C	0.75	1
4-15	.12 mi. E. 4-14	Poor A, C, and rock	0.75	1
4-16	.10 mi. E. 4-15	Poor A, C, and rock	1.0	2
4-17	.11 mi. E. 4-16	Poor A, C, and rock	1.25	1
4-18	.10 mi. E. 4-17	Poor A, C, and rock	1.25	5
4-19	.10 mi. E. 4-18	Poor A, C, and rock	1.25	1
4-20	.10 mi. E. 4-19	A, C, and rock	1.25	1
4-21	.10 mi. E. 4-20	Poor A, C, and rock	1.25	2
4-22	.10 mi. E. 4-21	A, C, and rock	0.75	1
4-23	.10 mi. E. 4-22	A, C, and rock	0.75	1
4-24	.11 mi. E. 4-23	A, C, and rock	1.75	1

1/A zone is organic humus-bearing layer soil partly decomposed.
2/C zone is yellow to red-brown soil overlying bedrock; B zone absent in sampled areas.
3/Charcoal in soil results from old forest fires; may mask end point of titration.

APPENDIX

Sample no.	Location	Description	Mercury sensor	Heavy metals
		Leigh Creek Traverse--continued		
4-25	.10 mi. E. 4-24	Poor A, C, and rock	1.50	1
4-26	.10 mi. E. 4-25	Poor A, C, and rock, below adit	1.25	1
4-27	.10 mi. E. 4-26	A, C, and rock	1.25	1
4-28	.13 mi. E. 4-27	A, C, and rock	1.75	1
		Smearl Creek (walking traverse)		
5-0	Above Snowshoe fault	Poor A and C, on bedrock	1.25	1
5-1	Above Snowshoe fault	Poor A and C, on bedrock	2.50	1
5-2	On fault	Mixed A and C zone	2.50	1
5-3	At falls near fault	Mixed A and C zone	3.25	1
5-4	In timber E. of fault	Mixed A and C zone	1.75	1
5-5	In timber E. of fault	A, C, with gravel	1.75	2
5-6	In timber E. of fault	A, C, with gravel	2.25	5
5-7	In timber E. of fault	A, C, with gravel	2.0	2
5-8	In timber	Mixed A and C zone	2.0	1
5-9	In timber	C, with gravel	1.50	1
		Poorman Creek		
6-1	On fault	A and C zone	2.25	5
6-2	E. of fault	C, with rock	3.0	1
6-3	E. of fault	A and C zone	2.0	4
6-4	E. of fault	C zone	2.0	2
6-5	E. of fault	C zone	3.0	1
6-6	E. of fault	C zone	2.25	1
6-7	E. of fault	C zone	2.75	1
6-8	E. of fault	C zone	2.75	1
6-9	E. of fault	C zone	3.0	1
6-10	Road traverse commenced	A, C, and rock	3.0	2
6-11	.10 mi. E. 6-10	A, C, and rock	2.0	1
6-12	.10 mi. E. 6-11	A, C, and rock	2.0	1

6-13	.10 mi. E. 6-12	A, C, and rock	2.0	1
6-14	.10 mi. E. 6-13	C zone	2.5	1
6-15	.10 mi. E. 6-14	C zone	3.0	1
6-16	.10 mi. E. 6-15	C and rock	3.25	1
6-17	.10 mi. E. 6-16	Good C zone	3.0	1
6-18	.10 mi. E. 6-17	A, C, and rock	2.0	1
6-19	.20 mi. E. 6-18	A, C, and rock	2.25	1
6-20	.22 mi. E. 6-19	C zone	1.5	2
6-21	.10 mi. E. 6-20	Good C, with rock	1.0	1

Granite Creek Traverse

7-1	Above Snowshoe fault	C and rock	1.0	1
7-2	Above Snowshoe fault	C and rock	1.25	2
7-3	0 mi. on fault (commence road traverse)	A, C, silt, and rock	1.0	3
7-4	.10 mi. E. 7-3	Thin C, sand, and rock	1.0	4
7-5	.12 mi. E. 7-4	Sandy	1.0	2
7-6	.10 mi. E. 7-5	Minor C, with silty sand	0.25	1
7-7	.13 mi. E. 7-6	Silt, C, and charcoal	0.75	2
7-8	.07 mi. E. 7-7	C, with sand	0.75	1
7-9	.10 mi. E. 7-8	Good C zone	0.75	2
7-10	.10 mi. E. 7-9	Good C zone	0.75	2

Cable Creek Traverse

8-1	E. of fault in timber	A, C, with rock	2.0	4
8-2	240 ft. E. of fault	Good C zone	3.25	2
8-3	250 ft. W. of fault	Good C zone, with rock	3.25	2
8-4	650 ft. W. of fault	A, C, and rock	3.0	6
8-5	580 ft. W. of fault	A, C, and rock (poor)	3.5	6
8-6	320 ft. W. of fault	A, C, and rock	3.0	4
8-7	W. of fault or on fault	A, C, and rock	3.75	4
8-8	420 ft. W. of fault	A, C, and rock	3.25	5
8-9	80 ft. W. of fault	A, C, and rock	3.5	3
8-10	W. of fault, N. side Cable Creek	A, C, and rock	2.0	2
8-11	85 ft. E. of fault	Good C zone	1.25	2
8-12	170 ft. E. of fault	C zone	0.75	8
8-13	.20 mi. E. 8-12	Good C zone	1.0	2
8-14	.10 mi. E. 8-13	C and rock	1.5	2
8-15	.10 mi. E. 8-14	Good C zone	1.0	1
8-16	.10 mi. E. 8-15	Poor A and C, with sand	1.0	1

APPENDIX

Sample no.	Location	Description	Mercury sensor	Heavy metals
		Cable Creek Traverse--continued		
8-17	.13 mi. E. 8-16	Good C zone	1.25	1
8-18	.07 mi. E. 8-17	Good C zone	1.0	6
8-19	.10 mi. E. 8-18	Good C zone and rock	1.25	16
8-20	.10 mi. E. 8-19	Good C zone and rock	1.25	8
8-18R4/	N. road bank, same as 8-18	C zone, good mineral soil	2.75	8
8-19R4/	N. road bank, same as 8-19	Good C zone, with rock	2.0	14
8-20R4/	N. road bank, same as 8-20	Good C zone, with rock	2.25	12-14
8-21	.10 mi. E. 8-20	Good C zone, sampled above culvert	2.50	2
8-22	.09 mi. E. 8-21	Good C zone, talus slope 150 ft. E.	2.0	2
8-23	.14 mi. E. 8-22	Good C zone, talus slope 100 ft. E.	1.5	2
		Snowshoe Vein Traverse		
9-1	15 ft. W. tunnel above zero adit5/	Mixed A and C zone	2.75	10
9-2	Footwall of 2d tunnel above zero adit	Mixed A, C, and rock	1.5	10
9-3	On vein 20 ft. S. 3d dump above zero adit	Good A, fair C zone	3.0	25++
9-4	On outcrop W. of dump base, W. of small creek	A, C, and rock	3.5	18
9-5	4th tunnel above zero adit	Mixed A, C, and rock, on vein	4.25	25++
9-6	5th tunnel above zero adit	Mixed A, C, and rock, on vein	4.5	25++
9-7	On vein above small cut	A, C, and rock	4.25	25++
9-8	Opposite talus base on vein	Mixed A, C, and rock, poor soil	4.25	10
9-9	Opposite upper end talus slope	Mixed A and C, on vein(?)	4.50	4
		Cable Creek Snowshoe Vein Traverse		
10-1	In trees, tree blazed	Good A and C	3.75	6
10-2	At cabin, 200 ft. E. of creek	Mixed A, C, and rock	3.75	8

10-3	550 ft. N. of cabin, tree blazed	Good C, with rock	3.75	6
10-4	25 ft. W. of E. lower adit	A, poor C, and rock	3.50	16
10-5	At E. 2d adit, soil over vein	A, C, and rock	3.0	25++
10-6	Ridgetop, between Cable and Bear Creeks	A, C, and rock, at small pit	3.75	2
10-7	Opposite W. top adit, axis of drag fold	A, C, and rock	4.0	6
10-8	Above W. upper dump, at tree base	Poor sample, mostly A, some C	3.75	6
10-9	50 ft. below massive siliceous outcrop	Very poor sample, A, with little C	5.0	16
10-10	350 ft. below massive siliceous outcrop	Good C zone at tree base	3.25	25+
10-11	In small creek bank, 225 ft. E. to timber	Good C zone	3.5	9
10-12	900 ft. N. end of Cable Creek road	Good C at tree base	3.25	6

4/ Location resampled to check heavy metal anomaly at stations 8-18 to 8-20.
5/ Zero adit located at end of Snowshoe Creek road about 330 ft. east of old millsite.

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