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

BULLETIN 36

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

5. Western Flathead County and Part of Lincoln County

By

W. M. Johns, A. G. Smith, W. C. Barnes,
E. H. Gilmour, and W. D. Page

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

MONTANA SCHOOL OF MINES
Butte, Montana
September 1963

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ABSTRACT

The mapped areas, totaling 1,685 square miles, are situated in the Whitefish and Salish Mountains and northern parts of the Swan and Mission Ranges in Lincoln, Flathead, and Sanders Counties of northwest Montana.

These areas are underlain by argillite, quartzite, and carbonate-bearing rocks of the Belt Series (Precambrian), amounting to 25,000 feet in thickness. Belt Series strata consist of three major groups, which have been subdivided into six formations and three unnamed mappable units. The Kishenehn Formation (Tertiary) in the North Fork Valley and Tertiary conglomerate, sandstone, and volcanic flows in the Horse Plains quadrangle are described. Pleistocene valley glaciers and the Cordilleran ice sheet deposited drift overlain by glaciolacustrine silt.

Structurally, the map areas are characterized by open folds, which are broad, gentle, and symmetrical. Stronger folding produced some northeast asymmetry. Northwest-striking normal faults, the largest of which is the Swan fault which has a stratigraphic throw exceeding 10,000 feet, are displaced by east-trending transverse or wrench faults. Some northwest-trending faults are present.

Significant amounts of silver, gold, lead, and copper have been produced from the Flathead and West Flathead mines of the Hog Heaven district 22 miles southwest of Kalispell. Extensive hydrothermal alteration is associated with silver-lead replacement deposits in Tertiary volcanic rocks and sedimentary rocks of the Ravalli Group (Precambrian). Nonmetallic deposits throughout the quadrangles are varied but small.

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

This report describes the results of reconnaissance mapping during the summer of 1962 for the fifth year of a six-year program in central and southwestern Flathead County and a small part of Lincoln and Sanders Counties. The mineral survey of Lincoln and Flathead Counties and northern Lake County in northwest Montana is jointly sponsored by the Great Northern Railway and the Pacific Power & Light Company under the supervision of the Montana Bureau of Mines and Geology.

The Kootenai-Flathead program was begun in 1958 to encourage development of mineral resources through a mapping project and a minerals-identification service in Kalispell. Four annual progress reports have been published by the Montana Bureau of Mines and Geology on the Yaak River, Thompson Lakes, Ural, and Pleasant Valley 30-minute quadrangles as Bulletins 12, 17, 23, and 29.

This report differs from previous Kootenai-Flathead bulletins, as it is the combined efforts of five authors submitting geologic data from their respective map areas to be assembled within one report. This procedure was necessitated by the complex geology within the quadrangles, such as facies changes in the upper Ravalli Group within quadrangles across the Rocky Mountain Trench, complexity of structure within the trench, and mineralization associated with igneous rocks in the Hog Heaven district. Credit for mapping and geologic interpretation is consequently limited to each author's respective field area.

The four map areas (index map, fig. 1) include parts of the Salish and Whitefish Mountains and the northern Swan and Mission Ranges and the intervening valleys of the Stillwater, Flathead, and Swan Rivers, which occupy the Rocky Mountain Trench, all these topographic features lying within part of the northern Rocky Mountain physiographic province.

Geologic data obtained during field work were plotted on U.S. Forest Service planimetric base maps. For the Whitefish Mountains, additional control was obtained by transferring contours from enlargements of the U.S. Geological Survey Kintla

Lakes and Stryker topographic sheets to the Forest Service base. Soil Conservation Service aerial photographs provided supplementary control for plotting field observations.

SCOPE OF REPORT

Four areas totaling 1,685 square miles (pl. 1 to 4) were mapped by six men during the summer of 1962. William Page and Ernest Gilmour spent three months in the field mapping 210 and 260 square miles, respectively. Willis Johns, assisted by Wayne Newell during the summer months, spent five months in the field mapping 800 square miles in the Kalispell vicinity. Alan Smith and William Barnes mapped 415 square miles during a six-week period in the Stryker and Kintla Lakes quadrangles east of U.S. Highway 93.

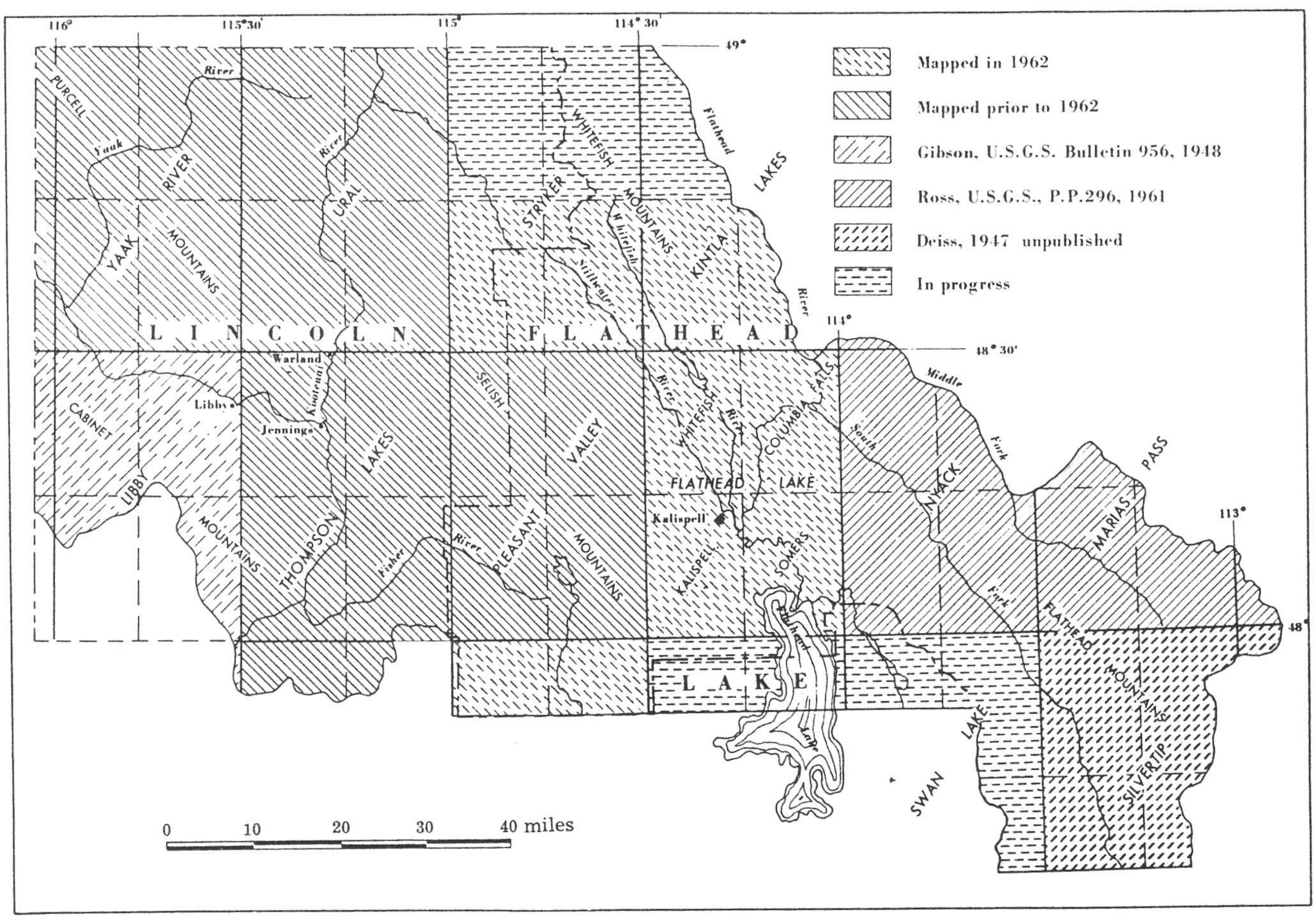

Figure 1.--Index map of northwest Montana showing location of quadrangles.

ACKNOWLEDGMENTS

The cost of the project was mainly supported by Kootenai-Flathead funds supplied jointly by Pacific Power & Light Company and Great Northern Railway Company for the fiscal year 1962. The Montana Bureau of Mines and Geology and the Yellowstone-Bighorn Research Association cosponsored field mapping in the southern Whitefish Mountains by Smith and Barnes. The Warren O. Thompson fund at the University of Colorado financed thin sections for William D. Page.

The authors are grateful to Mr. U.M. Sahinen, Associate Director, Montana Bureau of Mines and Geology; Mr. R.A. Watson, Geologist, Great Northern Railway Company; and Mr. G.A. Duell, Staff Geologist, Pacific Power & Light Company; for the supervisory planning, editing of the manuscript, and assistance throughout the program; to Dr. John C. Maxwell of Princeton University for checking the work of Mr. Barnes and Mr. Smith, and also for detailed mapping in the Ural NE quadrangle to be incorporated in the final map; to Prof. Donald Winston of Montana State University for checking Mr. Gilmour's mapping; and to Dr. John Chronic of the University of Colorado and Dr. Robert M. Weidman of Montana State University for assistance and criticism of written sections submitted by Mr. Page and Mr. Gilmour respectively, on the Horse Plains and Stryker quadrangles.

Willis M. Johns was ably assisted in the field by Wayne L. Newell of Franklin and Marshall College, Lancaster, Pennsylvania. All maps and tables and several illustrations were drafted by R.B. Holmes, Bureau draftsman. Mineral samples were assayed by the Montana Laboratory Company of Philipsburg and by Goodall Bros. of Helena, Montana.

The authors appreciate the help provided by many individuals, including Ted Ross of Polebridge; Tom Crum of Columbia Falls; Mr. and Mrs. Earl Scott, Buck Calvert, and Ed Smith of Olney; Vance Williford and Walter Bissell of Whitefish, Waino Lindbom, Oscar Oftedahl, Allen Harvey, Guy Maycumber, Herb Poston, Glen Bauska, John and Paul Jense, Norman Stringfellow, Oscar Moen, Ray Hough, and Mr. and Mrs. Aamodt of Kalispell; and to various members of the U.S. Forest Service Ant Flat and Hungry Horse Ranger Stations, and the State of Montana Stillwater Ranger Station at Olney.

Anaconda Mining Company and Northern Pacific Railway managements gave access privileges to their mining properties in the Hog Heaven mining district and also gave permission to examine maps and reports of their mining activities in the area.

PREVIOUS WORK

Previous work in the map areas comprises both reconnaissance and detailed mapping of the Belt Series, reports on glaciation and physiography of the region, and a study of mining properties in the Hog Heaven district.

During the period 1921 to 1924 a group including G.S. Lambert, A. Bevin, and C.H. Clapp, mapped the Salish Mountains in western Flathead County; this mapping was used by C.P. Ross for part of the geologic map of Montana published in 1955. Reconnaissance mapping by C.H. Clapp (1932) extends northwestward from the Missoula-Drummond-Helena area to Whitefish Lake and the southern Whitefish Mountains. Belt rocks in the Whitefish Mountains were studied by G.L. Sweeney (1955) under the auspices of the Great Northern Railway Co. The origin of the southern Rocky Mountain Trench from the 49th parallel through Flathead Lake and Swan Valley was discussed by Leech (1959). Detailed work includes a report by Shenon and Taylor (1936) on the Flathead mine and adjacent properties in the Hog Heaven mining district, and by Erdmann (1944, 1947) on structure, glaciation, and economic geology of the Hungry Horse dam site and reservoir area and other proposed sites on the Flathead River and North Fork Flathead River. Alden (1953) briefly described the physiography of the Flathead Lake region. Physiographic studies led Pardee (1950) to postulate block faulting in the Swan, Flathead, and Stillwater Valleys.

Other work in both noncontiguous and adjoining areas of the Lewis and Livingston Ranges and the Whitefish and Flathead Mountains includes studies of Belt rocks by Willis (1902), C.L. and M.A. Fenton (1937), Daly (1912), Ross (1959, 1960), and Bentzin (1960). Price (1962) published descriptions of Precambrian, Paleozoic, Mesozoic, and Cenozoic rocks in southeastern British Columbia and southwestern Alberta. Rezak (1957) made a comprehensive study of stromatolites in Glacier Park. Two private reports on the Independence copper deposit in the northern Whitefish Mountains were submitted by Channing (1896) and Fassett (1904) to private individuals.

G E O G R A P H Y

LOCATION AND ACCESSIBILITY

The Stryker and Kintla Lakes quadrangles (pl. 1) lie north of Whitefish and southeast of Eureka, Montana, in Flathead County and a small part of northeastern Lincoln County, and include the northern Salish Mountains, the Stillwater Valley, and the south part of the Whitefish Range. A triangular portion of the Stryker quadrangle west of U.S. Highway 93 was mapped by

E.H. Gilmour; the rest of the Stryker quadrangle and the Kintla Lakes quadrangle west of the North Fork Flathead River were mapped by A.G. Smith and W.C. Barnes. The map area is bounded on the south by lat 48°30' N., on the north by lat 48°45' N., on the west by the 115th meridian, and on the east by the North Flathead River.

The second map area (pl. 2 and 3) includes the Columbia Falls, Whitefish, Kalispell, and Somers 15-minute quadrangles in Flathead County; the area is bounded on the north by lat 48°30' N., on the south by lat 48° N., on the west by long 114°30' W., and on the east by long 114° W. These quadrangles include chiefly the Flathead and south Stillwater Valleys, although peripheral parts include the eastern Salish and extreme southern Whitefish Mountains and the northern extremities of the Swan and Mission Ranges. Kalispell is near the center of the map area.

The north quarter of the Horse Plains quadrangle (pl. 4) lies in parts of Flathead and Sanders Counties, in the south part of the Salish Mountains about 15 miles west of Flathead Lake. The map area is southwest of Kalispell and northwest of Polson; the town of Niarada is situated six miles south of the southern boundary. The boundaries of the Horse Plains map area are lat 47°52'30" N. on the south, lat 48° N. on the north, long 115° W. on the west, and long 114°30' W. on the east.

Kalispell is at the junction of north-south U.S. Highway 93 and east-west U.S. Highway 2, and is served by a branch of the Great Northern Railway. Communities also served by the railway are Libby, Eureka, Whitefish, Columbia Falls, and other points east. Roads serving the valleys are State Highway 35 following the east shore of Flathead Lake, State Highway 40 connecting Whitefish and Columbia Falls, and State Highway 28 joining Plains and Elmo through Camas Valley. County and Forest Service roads including the North Fork road; Forest Service maintained logging roads up Big Creek, Canyon Creek, and Coal Creek; Basin Creek-Sunday Creek road; Martin Creek road; Truman Creek road; the Thompson River and Little Bitterroot roads; and the road linking Kila and Niarada via the Flathead mine, provide access to the greater part of all map areas including the western Horse Plains quadrangle. Numerous logging roads and some Forest Service trails provide means of entering the less accessible sections.

TOPOGRAPHY AND DRAINAGE

The Whitefish Range is one of rugged mountainous terrain trending northwestward and rising to altitudes of 7,500 feet in the map area. Bounding the range on the west is the Stillwater Valley lying within the Rocky Mountain Trench at an altitude of

3,000 feet. To the east the North Fork Valley at an altitude of 3,200 feet separates the Whitefish Mountains from the ranges in Glacier National Park. The local relief within the area averages about 2,500 feet but is as much as 4,000 feet in the western part. In the triangular portion of the Stryker quadrangle in the Salish Mountains lying southwest of U.S. Highway 93, the topography is more subdued, higher peaks ranging from 5,200 feet to 5,600 feet in altitude.

The areas are in a mature stage of dissection and are drained by the North Fork Flathead River, Stillwater River, Whitefish Creek, and Lake, Swamp, and Fortine Creeks, tributaries of the Tobacco River. Tributary streams to the North Fork include Coal Creek, Canyon Creek, Big Creek, whereas Sunday Creek and Good Creek are major tributaries of the Stillwater River.

Within Flathead Valley, altitudes range from the water level of 2,893 feet at Flathead Lake to about 3,000 feet at Whitefish Lake. Topography on the west side of the valley consists of rolling ridges, the north slopes sparsely timbered and south slopes open. In the southern part of the Kalispell quadrangle, Blacktail Mountain rises to an altitude in excess of 6,700 feet. The northern Swan Range, bounding the east side of the Flathead Valley and the west side of Hungry Horse Reservoir, is precipitous and rugged and rises to altitudes above 7,000 feet. The Stillwater and Whitefish Rivers and Ashley Creek join the Flathead River east of Kalispell. North-flowing tributary streams to Ashley Creek are Mount and Truman Creeks.

In the Horse Plains quadrangle, the surface rises from low rolling mature hills of the eastern half to culminate in a 7,000-foot ridge lying between the Thompson and Little Bitterroot Rivers. Numerous small streams feed these two south-flowing rivers, which occupy valleys at altitudes of about 3,300 feet.

CLIMATE AND VEGETATION

Temperature and precipitation records for Flathead Valley were obtained from the U.S. Weather Bureau at the Flathead County Airport, 11 miles north of Kalispell (tables 1 and 2).

Table 1.--Temperature and precipitation records at Flathead County Airport, 1956-61.

Year	Average for year	Maximum °F	Maximum Date	Minimum °F	Minimum Date	Precipitation in inches[1]
1956	42.7	91	Aug. 23	-25	Feb. 16	17.07
1957	42.4	92	July 13	-28	Jan. 26	12.44
1958	45.5	95	Aug. 25	-9	Nov. 27	18.00
1959	41.3	97	July 23	-28	Nov. 16	20.97
1960	41.2	104	July 19	-29	Mar. 3	14.24
1961	44.0	105	Aug. 4	-14	Dec. 11	16.40

[1]Includes snowfall amounts of about 68 inches annually.

Table 2.--Annual and monthly maximum and minimum temperatures at Flathead County Airport, 1956-61 (temperature in °F).

Year	Ann.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1956	53.7	29.8	29.3	39.4	55.2	66.6	70.1	81.4	77.8	70.1	53.2	37.1	34.6
	31.6	14.5	10.7	22.1	31.8	42.2	44.5	50.5	46.4	39.3	34.2	22.1	21.1
1957	53.7	17.9	32.1	41.9	53.9	69.7	71.9	81.1	78.0	72.5	48.8	39.3	37.7
	31.0	1.2	11.1	23.3	32.5	43.1	46.1	47.9	48.0	38.2	32.6	23.1	24.4
1958	56.5	33.6	36.3	43.9	53.0	76.3	73.7	79.5	85.5	68.3	56.6	38.1	32.9
	34.4	22.4	22.1	23.3	33.4	44.3	49.3	50.9	51.0	40.6	30.5	23.6	21.0
1959	52.3	30.5	31.1	42.9	54.5	59.3	72.2	82.6	74.9	64.1	53.1	31.6	31.2
	30.3	14.9	14.0	25.7	32.4	35.6	46.2	46.9	44.8	41.6	31.7	12.5	17.1
1960	53.5	23.2	29.6	38.0	54.5	61.9	76.6	91.2	75.6	73.0	57.2	28.3	26.9
	28.8	5.4	8.9	16.5	31.5	38.4	43.3	48.4	46.4	36.3	29.6	24.3	16.1
1961	55.8	31.5	41.5	46.5	50.2	64.0	81.5	87.1	88.6	62.5	51.9	35.3	28.6
	32.1	16.3	29.4	26.8	30.7	40.7	46.9	50.7	49.6	35.7	28.1	17.8	12.9

The mountainous areas are covered with pine, fir, spruce, and other conifers; the valleys and bordering foothills support sparser timber growth, grass, and brush. A large part of Flathead Valley between Whitefish and Flathead Lake is tillable land producing excellent stands of wheat, rape, and other crops. Considerable grazing land within the valley supports a thriving cattle industry. Lumbering, one of the essential industries in Flathead and Lincoln Counties, operates on the basis of sustained yield on both Federal and private land.

GLACIATION

Pleistocene glacial deposits and associated lacustrine silt and sandy silt in the major valleys of the map areas north of Flathead Lake have a complex history. Glacial drift composed of till and outwash is found in all major valleys in the southern part of the Whitefish Range. Local areas of thick moraine are found on the west side of the valley of the North Fork Flathead River. Glacial deposits, except some sand and till on the Flathead River upstream from Columbia Falls and silt and gravel of questionable age southeast of Olney, are believed to be of Wisconsin age.

While investigating Hungry Horse, Badrock Canyon, Coram Canyon, and Lower Canyon Creek dam sites, Erdmann (1944) tentatively recognized two sheets of pre-Wisconsin glacial till or bouldery clay and two possible pre-Wisconsin interglacial river deposits on the upper Flathead River and the North Fork and South Fork tributaries. He judged some of the material to be pre-Wisconsin on the basis of weathering, induration, hardness, and other characteristics. In the NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 5, T. 30 N., R. 19 W., he measured an incomplete section of 35 feet of Wisconsin till overlying 114 feet of older stream gravel. Another section of Wisconsin drift and pre-Wisconsin deposits totaling 150 feet was measured on the left bank of the Flathead River in sec. 17 and 20, T. 31 N., R. 19 W. Subsequent studies convinced Erdmann that all material below Wisconsin till, in both sections, is Tertiary (Ross, 1959, p. 68). Alden (1953, p. 124) measured a bluff section halfway between Columbia Falls and the mouth of Badrock Canyon in which he regarded the lower 45 feet of the section as pre-Wisconsin stratified deltaic sand overlying older pre-Wisconsin glacial till.

The seeming absence of deposits older than Wisconsin age in the Rocky Mountain Trench, except for possible Tertiary silt and pre-Wisconsin gravel southeast of Olney, might be explained in two ways: The older deposits may have been eroded or they may be covered by the deposits left by the Cordilleran Wisconsin ice sheet. It seems probable that remnants of older glacial deposits may underlie Wisconsin drift in parts of the Stillwater and Flathead Valleys. The pre-Wisconsin glacial deposits east of Columbia Falls may be exposed because the Flathead River, above Badrock Canyon, and its North and South Fork tributaries have been actively cutting through surficial material to expose older beds. They may have been preserved because the valley glaciers that moved down these tributaries may not have removed older drifts as effectively as did the Cordilleran ice sheet west of the Whitefish Mountains.

The Cordilleran ice sheet in Wisconsin time (fig. 2) fringed the northern boundary of the Horse Plains quadrangle while several small valley glaciers were concurrently present in the mountains east of the Thompson River. The valley glacier deposits (pl. 1) are small and thin and consist predominantly of till and moraines, which are expressed topographically. The small size and areal extent of their deposits indicate that the glaciers in the mountains persisted only briefly.

In Kalispell Valley, late Pleistocene glacial drift, lakebed silt, and alluvium are mapped separately for the purpose of showing locations of the more accessible nearsurface sources of gravel and sand.

Ice Movement

Ice moving down Stillwater Valley, which is about 9 miles wide at Olney, in a direction about S. 20° E. was crowded against the west flank of the Whitefish Range. East of the north end of Whitefish Lake in the SW$\frac{1}{4}$ sec. 3, T. 31 N., R. 22 W. (fig. 2), glacial striae trend S. 50° E., and on Big Mountain road in the $SW\frac{1}{4}$ sec. 2, T. 31 N., R. 22 W., glacial scratches and grooving trend S. 50° to 57° E. indicating that direction of ice movement extended toward Columbia Falls diagonal to the south end of the Whitefish Range. At the same location on Big Mountain road in sec. 2, at an altitude of 4,400 feet, a set of striae trending S. 45° W. possibly indicates some slumping or local readjustment of ice above this altitude as the main glacier moved southeastward. Whitefish Lake is dammed by a recessional moraine (Alden, 1953); the town of Whitefish is situated on a dissected outwash terrace.

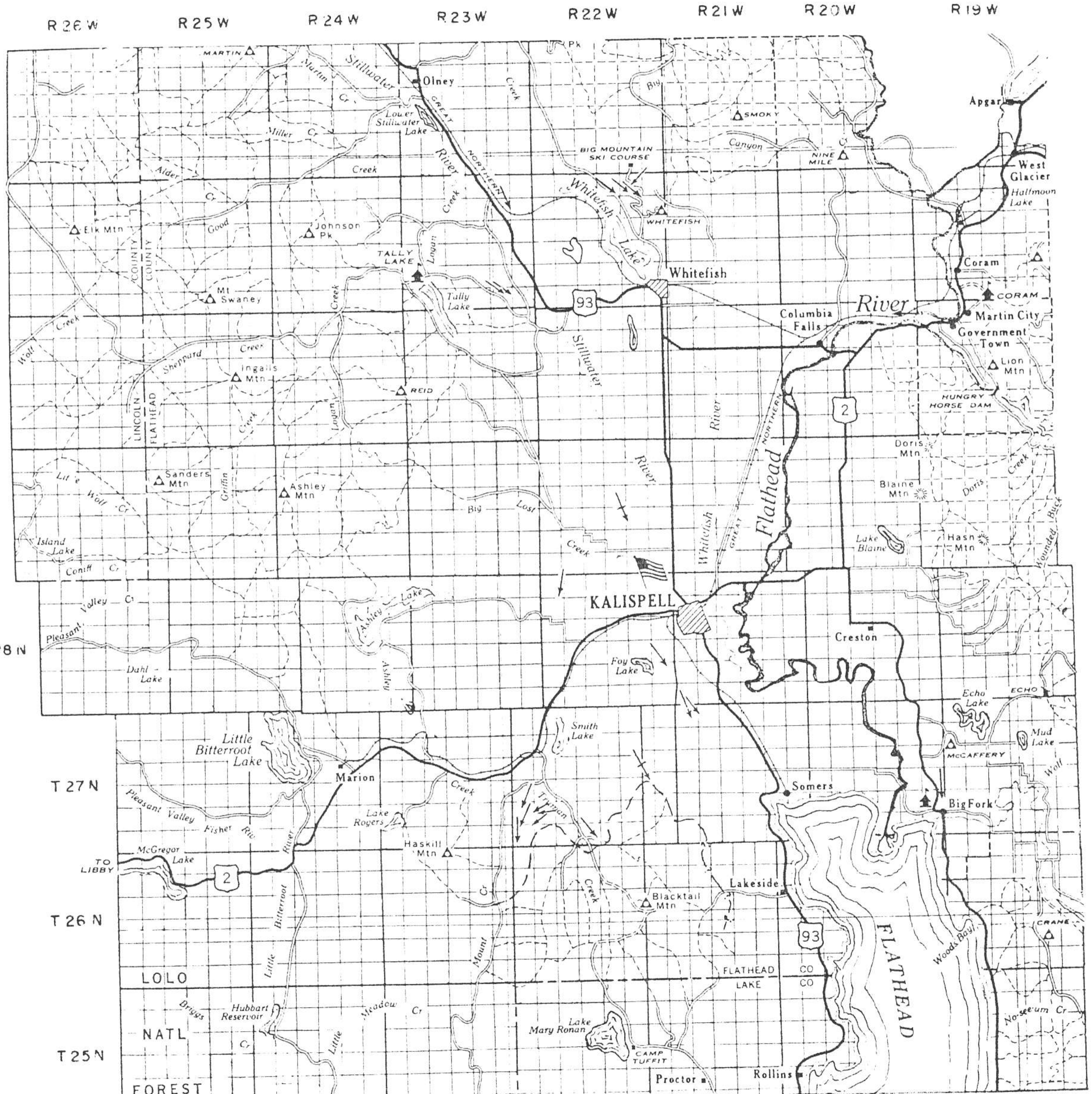

Figure 2.--Map showing extent and direction of movement of glaciers.

Erdmann (1944, p. 64) described a northwest-trending mountain glacier originating in local mountain ice fields and moving down the South Fork to unite at the mouth of Abbot Creek 2 miles north of Lion Hill with a south-trending smaller lobe descending the North Fork. The merging ice moved in a westerly direction down Flathead River through Badrock Canyon to join the glacial lobe from Stillwater Valley near Columbia Falls.

In the northwest part of the Flathead Valley, in the NE$\frac{1}{4}$ sec. 35, T. 31 N., R. 23 W., glacial striations on middle Piegan limestone strike S. 50° to 55° E. Farther south, in the NE$\frac{1}{4}$ sec. 22, T. 29 N., R. 22 W., lineaments on aerial photographs suggest that the ice moved S. 22° E.

At a point 4 miles west of Kalispell the ice movement continued to advance about S. 22° E., but there a lobe diverged southwesterly, for glacial striae in the SE$\frac{1}{4}$ sec. 6, T. 28 N., R. 22 W., strike S. 10° W. The southwest lobe continued past Kila up Ashley and Truman Creeks, and extended at least 1$\frac{1}{2}$ miles up Emmons Creek, for striae in the SW$\frac{1}{4}$ sec. 34, T. 27 N., R. 22 W., trend S. 40° E. Ice also crossed the ridge separating Truman and Mount Creeks; in the W$\frac{1}{2}$ sec. 29, T. 27 N., R. 22 W., striations trend S. 65° to 83° W., and in sec. 30 and 31, T. 27 N., R. 22 W., they trend S. 20° to 25° W. On the east side of Mount Creek, in the SW$\frac{1}{4}$ sec. 31, striae trend south, indicating that the ice advanced up this valley.

The southeast-trending lobe continued across Foy Lakes toward Lakeside and Flathead Lake, crossing Patrick, Bierney, and Stoner Creeks. On a slope east of upper Foy Lake the direction of ice movement was S. 35° E., and on the west side of Patrick Creek in sec. 6, T. 27 N., R. 21 W., the direction of movement was S. 20° to 40° E. The ice lobe reached a minimum altitude of 5,100 feet in the SW corner sec. 14, T. 27 N., R. 21$\frac{1}{2}$ W., where a small lake was dammed by southeastward movement of the glacier. Later recessional moraines are believed to have impounded Foy Lakes.

One lobe of the ice sheet penetrated southward down the Thompson River Valley, "plastering" the valley walls with glacial deposits of hummocky till and small moraines. Subsequently, outwash alluvium was deposited in the valley bottom.

Glacial Topographic Features

In the south part of the Whitefish Mountains the topography is only slightly modified by glaciation. Small cirques developed around Stryker, Standard, and Moose Peaks and at the head of Hay Creek.

Alden recognized a recessional lateral moraine, west of the Stillwater River, extending from the mouth of Lost Creek to

Kalispell. This belt of swales, ponds, and kettle holes he named the Kalispell moraine (1953, p. 123). He described the terminal moraine just north and east of Kalispell as a recessional feature that has been almost removed by the Stillwater, Whitefish, and Flathead Rivers, leaving only dissevered remnants of moraine. On the east side of Flathead River, between U.S. Highway 2 bridge and the old U.S. Highway 2 bridge about a mile south, is a feature described by Alden as another remnant of the Kalispell terminal moraine. At the southeast end of the remnant a Flathead County gravel pit has exposed south-dipping stratified gravel and sandy gravel that may have been deposited as a delta when the water surface in the valley was at an altitude between 3,000 and 3,100 feet. A conspicuous terrace is present at an altitude of 3,000 feet, and buff silts overlap at the easternmost end of the gravel pit, slightly above this altitude. The silt layers at several locations have been bent into inverted, smoothly curved V's (periglacial involutes?), possibly by frost heaving. Horizontal beds occur above and below the contorted beds.

Upper parts of Sand and Fawn Creeks on the east slope of the north part of the Swan Range have well-developed U-shaped valleys cut by valley glaciers moving northeast toward the South Fork Flathead Valley. Cirques are conspicuous on the upper tributaries of Aurora and Fawn Creeks and on the north side of Doris Ridge divide.

As the ice mass moved south from Columbia Falls, the glacier was crowded against the west flank of the Swan Range from Badrock Canyon to the vicinity of Lake Blaine. Along the east side of Flathead Valley, as the ice mass moved south, it ground against projecting spurs beveling them into facets. A prominent hanging tributary forms a falls above the mouth of a small drainage in the NW$\frac{1}{4}$ sec. 35, T. 30 N., R. 20 W. Small alluvial fans from hillwash were observed in sec. 14, T. 29 N., R. 20 W., and another dissected alluvial fan is present northeast of upper Lake Blaine. The fans consist of gravel eroded from mountain flanks.

Between the mouth of Mill Creek, 1$\frac{1}{2}$ miles southeast of Lake Blaine, and Echo Lake near the junction of Swan and Flathead Valleys, is a strip of low interconnecting ridges between small lakes locally referred to as "The Potholes." A valley glacier, originating from canyons on the east flank of the north part of the Mission Range and to a lesser extent from drainages east of Swan Valley, advanced down Swan River in a northerly direction to meet the larger south-advancing lobe occupying Flathead Valley. The pothole and ridge topography may represent terminal moraine of the Swan Valley glacier; the deposits, including kettles, ridges, swales, and several sinuous ridges believed to be eskers, were laid down when movement of the Swan Valley glacier was retarded by ice in Flathead Valley.

Glacier striae a mile northwest of Bigfork in the NE$\frac{1}{4}$ sec. 25, T. 27 N., R. 20 W., indicate that the direction of flow of Flathead Valley ice continued south.

Thin and poorly exposed glacial deposits at the head of Mount Creek (pl. 1) are a form of drift, that is, ice-rafted material that includes large boulders deposited from a glacial lake at the head of Mount Creek. The lake was dammed in the north by glacier ice and had a southern outlet over the low pass (sec. 10, T. 25 N., R. 23 W.) at an altitude of about 4,700 feet into a tributary of Sullivan Creek (Alden, 1953). This tributary (sec. 9, 10, and 16, T. 25 N., R. 23 W.) occupies an anomalous gorge, as an underfit, intermittent stream. Brown's Meadows on Mount Creek are underlain by lake-bed silt and clay (pl. 1), but these deposits are at least partly post-glacial. Damming by the terminal moraine caused part of the lake to remain after recession of the ice. Since then it has been filled with debris.

According to Richmond (1963, personal communication) and Alden (1953, p. 154), glacial Lake Missoula, which existed during at least three glacial stages in Wisconsin time, had its highest level (altitude about 4,150 feet) prior to the late Wisconsin (Pinedale) advance. The lake drained at least twice, and the lake level fluctuated so that no one stand, or level, was of long enough duration for extensive wave-cut terraces to form. Near Little Meadow Creek, a fill terrace deposited from glacial Lake Missoula at one of its lower stands in Wisconsin time consists of 20 feet of brownish-gray clay and silt. Glacial Lake Missoula silts (Richmond, 1963, personal cummunication) are extensive south of Niarada. Moreover, scattered erratics of quartzite and gneiss, present below 3,800 feet altitude in the southern part of the map area, are ice-rafted material deposited from Lake Missoula.

Several gravel-capped terraces ranging up to 200 feet above the present river level are present in Little Bitterroot Valley near Hubbart Reservoir. The outwash gravel on the terraces ranges from a few feet to at least 50 feet in thickness and overlies Tertiary volcanic tuffs. The terrace levels were probably controlled by different stands of glacial Lake Missoula during the late Pleistocene.

Thompson River Valley is partly filled by glacial outwash, but is unterraced because the ice lobe protected it from the influence of Lake Missoula. A large, gravel-capped terrace at the mouth of Big Rock Creek, however, is below the terminal moraine of this lobe. It may have resulted from a high stand of glacial Lake Missoula, but more likely it is a pre-Wisconsin deposit. The low divide to the north of the terrace may be an early Pleistocene channel for the Thompson River.

ROCK TYPES

Argillite, quartzite, and carbonate rocks of the Belt Series (Precambrain) underlie the major part of the map areas. They are thick, conformable, and thinly laminated, and contain abundant sedimentary structures indicative of a shallow-water environment of deposition.

The lowest units exposed in the map areas belong to the Ravalli Group, which is divided into Appekunny and overlying Grinnell Formations or mapped as Ravalli undifferentiated west of the Rocky Mountain Trench.

Conformable strata of the Piegan Group or parts of the group are present in all map areas; the lower unit is identified as P_1, the middle unit as P_2, and the upper unit as P_3. The upper unit is missing west of the Rocky Mountain Trench, having been eroded. While mapping the Whitefish Mountains, William Barnes and Alan Smith mapped the group as the Siyeh Formation and subdivided it into lower, middle, and upper units. In this report, the Piegan Group name is retained to conform with terminology used in previous Kootenai-Flathead progress reports.

Missoula Group strata in ascending order are the Shepard, Kintla, Phillips, and Roosville Formations, all conformable.

The Kishenehn Formation (Tertiary) lies unconformably upon Missoula Group strata in the valley of the North Fork Flathead River northwest of Glacier View Mountain. The strata consist of sandstone, mudstone, and minor lignite. They are very poorly exposed, but outcrops along the Flathead River indicate that they dip uniformly to the northeast at moderate to steep angles.

An extrusive basic amygdaloidal and pillow lava, the Purcell Basalt, is present in the southern part of the Whitefish Range. It decreases in thickness and wedges out several miles north of lat 48°30' in the southeast corner of the Whitefish Mountains.

Several types of igneous rocks occur in the north part of the Horse Plains quadrangle. Latite is extensively exposed in the Hog Heaven district, whereas andesite and basalt are locally present in the vicinity of the Hog Heaven district and the Hubbart Reservoir respectively.

Cenozoic sediments include glacial drift and till and unconsolidated sand, silt, and clay of sufficient thickness and continuity in some areas to be distinguished on the geologic maps. Recent alluvium bordering major streams and rivers consist in part of gravel and sand from reworked glacial deposits.

	Pleasant Valley quadrangle Johns	Kalispell & vicinity Johns, Gilmour, Page (this report)	Southern Whitefish Range Barnes & Smith (this report)	British Columbia Leech	Alberta & British Columbia Price	Glacier Park Ross
Missoula Group			(top eroded) Roosville 4,000+	(top eroded) Roosville 1,740	(top eroded) Roosville 3,500+	(top eroded) Undifferentiated Missoula Group 6,000+
			Phillips 650-700	Phillips 400	Phillips 500-700	
			Kintla 2,900-3,300	Gateway 2,000	Gateway 1,150-3,000	
			Shepard 400		Shepard (lower Gateway) 150-900	Shepard 400+
			Purcell lava 0-350	Purcell andesitic lava mapped at top of Siyeh	Purcell andesitic lava 0-600	Purcell Basalt up to 200+
Piegan Group	(top eroded) Middle 5,000+	(top eroded) Middle 5,800+	Upper 1,200-2,000	Siyeh and Kitchner 4,700-7,000	Siyeh 1,130-3,000	Lower Missoula Group 300±
			Middle 4,500-5,800			Siyeh 1,800-5,000
	Lower 3,200	Lower 2,700-3,000	Lower 1,250-3,200			
Ravalli Group	Ravalli 10,000	Ravalli 7,400+ (base not exposed)	Grinnell 2,500	Creston 6,000	Grinnell 350-1,700	Grinnell 1,000-4,000
			Appekunny 5,000+ (base not exposed)		Appekunny 1,500-2,000	Appekunny 2,000-5,000
					Altyn 500-4,000	Altyn 2,000± (base not exposed)
Pre-Ravalli Rocks	Prichard 2,500+ (base not exposed)			Aldridge 8,000+	Waterton 1,500 (base faulted)	
				Fort Steel 6,000+		

Correlation of Belt Series in vicinity of Kalispell with nearby areas.

BELT SERIES (PRECAMBRIAN)

Ravalli Group

Appekunny Formation.--The lowest exosed formation is the Appekunny of the Bėlt Series, found on the northeast side of the Whitefish Creek valley near Upper Whitefish Lake in the Stryker quadrangle; it is correlated with the Appekunny Formation of Glacier National Park. It consists of light-gray siliceous argillite that is very hard and compact, flaggy to slabby, and weathers medium orange brown or brownish gray. Limonite specks, which may be derived from the weathering of magnetite, are common. Some layers are composed of alternating thin laminae of light-gray and dark-gray fine argillite. The upper 3,000 feet of the formation is a light-gray or light-greenish-gray very fine grained quartzite that weathers pale yellowish gray and contains some interbedded thin laminae of medium-gray argillite. The quartzite contains small rhombic specks of limonite that may have once been crystals of ferroan dolomite. The argillite layers commonly contain mud-crack casts.

The thickness of the Appekunny Formation is difficult to estimate, as it is folded and the base is nowhere exposed, but it must be at least 5,000 feet. The upper part of the formation seems to be transitional into the overlying Grinnell Formation.

Grinnell Formation.--The Grinnell Formation was named Grinnell Argillite by Willis (1902, p. 322) from exposures on Mount Grinnell in Glacier National Park, where the formation is about 1,800 feet thick. In the eastern Stryker area, the Grinnell is exposed in the Rocky Mountain Trench and along the Whitefish divide east of Whitefish Creek.

Rocks of the Ravalli Group exposed in the trench area are lithologically similar to Willis' Grinnell Formation of the Livingston Range. Fenton and Fenton (1937, p. 1887) divided the Grinnell Formation into three members, but these members were not separable in the map area. William Barnes and Alan Smith (personal cummunication) have used the Glacier National Park terminology for the Ravalli Group in their recent study of the Whitefish Mountains. Ross (1959) included in the Grinnell Formation the greenish-gray calcareous argillite above the reddish sandy argillite and restricted the Siyeh Formation to the blue-gray "molar-tooth" limestone. Because the boundary between the reddish argillite and greenish dolomitic argillite is more easily mapped than the boundary between the "limestones", the term Grinnell Formation is applied in this report in the same manner as by Fenton and Fenton (1937).

The Grinnell Formation consists chiefly of purplish-gray coarse-grained argillite, grayish-red-purple fine-grained mud-cracked argillite, and interlaminated light-greenish-gray or pale-blue-green and grayish-red-purple argillite, especially near the top; minor interbedded units consist of interlaminated light-greenish-gray and greenish-gray argillite. Light-gray to white, fine- to medium-grained cross-bedded quartzite and quartzitic sandstone, containing purplish-gray mud chips, are interbedded with the argillite and serve to distinguish the formation from other grayish-purple sequences in the Belt Series. Most of the sandy layers are 1 to 6 cm thick, but some attain a thickness of 20 cm. Mud-crack casts and associated mud-chip breccia are found throughout the Grinnell Formation. Ripple marks are not common, but are occasionally found in the light-gray quartzite.

Two distinct textures are represented in the Grinnell. One is a bimodal sediment composed of clayey silt and various amounts of medium sand grains, and the other is a unimodal medium sand. The bimodal sediment (silt and sand) contains 10 to 70 percent sand grains. The rest is silt and clay in the ratio of about 70:30.

Sand grains range from 0.06 to 1.10 mm; mean size is 0.04 mm (medium sand). These grains are subround to round and thus indicate a high-energy source such as dunes or beaches but not rivers. According to Kuenen (1959), little or no rounding of sand particles is accomplished by rivers. Solitary rounded sand grains commonly occur along bedding planes within the silt and clay. Particles in the layered silt have a mean size of 0.03 mm (coarse silt) and are angular to subangular. The textural name for these sediments is immature coarse silty medium sandstone to immature medium sandy mudstone.

Particles in the unimodal sand have a mean size of 0.04 mm. They are well sorted, subround to round, supermature medium sandstone. The supermature sand forms interbeds in the silt and clay. Flat pebbles of clay and silt, probably derived from the underlying beds, occur in the sand layers.

The mineral composition of the sand and silt grains averages 90 percent quartz and 10 percent feldspar. Common quartz constitutes 80 percent and stretched metamorphic quartz grains less than 5 percent of the total sediment. Both orthoclase and plagioclase are present. The mean size of the rounded feldspar grains is less than that of the neighboring quartz grains. Quartz overgrowths cement most of the supermature sand layers. Less common are calcite and secondary dolomite cement.

From the foregoing description of the bimodal and unimodal sediments, the similarities are marked. The sand grains have a mean size of 0.4 mm and are subround to round in both textural types. Although the sand content varies, the silt-to-clay ratio is constant. The silt-clay component probably represents the material that was continuously deposited over much of the area, whereas the supermature sand grains were transported into the area of deposition only sporadically.

Cross-beds, ripple marks, and mud cracks are found in the Ravalli. All three features characterize the purplish-gray argillite and supermature sandstone beds of the Grinnell Formation. In the southwest corner of the SW Stryker quadrangle (Ravalli Group undifferentiated), however, these features are much less abundant, especially mud cracks and cross-beds. Well-developed ripple marks trend northwest in the southwest part of the map area.

In comparison of the Ravalli Group of the SW Stryker quadrangle to the Ravalli Group (Grinnell Formation) of the Rocky Mountain Trench, several similarities and differences are evident. The silt components in both localities are similar in shape and composition, but the mean silt size on the west is medium, whereas that of the east is coarse. The silt-to-clay ratio is about the same. Rounded sand grains are abundant in the northeast part of the area but are absent in the southwest part. The environment of deposition in the two areas seems to be similar, as interpreted from silt and clay (except for the slight eastward increase in mean silt size), but the eastern area had an influx of dune or beach sand.

The Grinnell Formation of Glacier National Park was compared to the Grinnell of the trench in the map area. Grain size, shape, and mineral composition are very similar. In the park the grains are subround to round, have a mean size of 0.3 mm, and are chiefly quartz but include a minor amount of smaller feldspar grains.

Many of the argillite beds of the Grinnell Formation contain numerous small rhombic cavities filled with a very fine grained mixture of quartz, illite, and limonite. Probably these cavities once contained crystals of siderite or ferroan dolomite, which have since been altered by weathering. They are more common in the coarser than in the finer argillite laminae.

The total thickness of the formation could be estimated only in the region near Diamond Peak, where it was found to be 2,500 feet. The contact with the overlying lower unit of the Piegan Group (P_1) is difficult to establish, as it is transitional through a sequence several hundred feet thick.

Although some geologists contend that the lithologic contact between the Grinnell Formation and basal Piegan is sharp throughout northwestern Montana, this was not found to be true in the Rocky Mountain Trench within the map area. A transition zone is well exposed on the south flank of Stryker Peak in the Whitefish Mountains, as was pointed out by Alan Smith, who mapped in the Whitefish Range. The same relationship is evident in traverses perpendicularly across the trench. In traversing the small hills in the trench, it is common to cross several sequences of greenish-gray and purplish-gray argillite in a vertical (stratigraphic) distance of 300 feet. A large part of the bedrock in the Rocky Mountain Trench in the map area is composed of beds in this transition zone. For convenience of mapping, all purplish-gray argillite is included in the Grinnell Formation except for the uppermost purplish-gray dolomitic argillite bed, which overlies nearly 200 feet of greenish-gray dolomitic argillite and is therefore included in the basal Piegan.

Ravalli Undifferentiated.--Ravalli rocks crop out along Fortine Creek in the southwest part of the Stryker quadrangle. Although nearly 30 square miles of Ravalli rocks were mapped in this area, the Ravalli section is not complete. The base of the Ravalli Group is not exposed, and because of faulting, the middle part of the group is missing. Bedrock is commonly obscured by glacial deposits and by vegetation. The uppermost Ravalli is well exposed along Fortine Creek road and Twin Meadows road, where the beds are vertical.

On the southeast flank of Davis Mountain, the quartzite layers of the Ravalli Group form resistant ledges. This is characteristic of Ravalli quartzite over much of northwestern Montana (Shelden, 1961, p. 16; Hall, 1962, p. 27; Johns, 1960-62). The resistant ledges are on the antidip slope of the northwestward-plunging Elk Mountain anticline. This slope should contain the contact between the lower and middle Ravalli Group (Hall, 1962, p. 28), but because both units are quartzitic and generally cover the underlying slopes with talus and because of the thick cover of vegetation, the Ravalli could not be subdivided into units.

Megascopically, the Ravalli Group consists of interbedded argillite, sandy argillite, and quartzite. These rocks range from different shades of gray to greenish gray and purplish gray. The quartzite tends to be gray, and the argillite is commonly greenish or purplish gray. Stratification also varies in the Ravalli Group. Generally, quartzite is thin to thick bedded, and argillite is laminated to thin bedded. The stratification of the laminated and very thin bedded argillite is emphasized by the alternation of purplish with greenish beds or laminae. This is especially characteristic of the uppermost 3,000 to 4,000 feet of the Ravalli.

At several locations in the Horse Plains quadrangle peculiar structures are present. The rounded, convex upward structures are smoothly irregular but differ in size. They are crudely analogous to ripple marks; wave lengths attain 14 cm and heights 5 cm.

These structures may be ripple marks but more probably are sedimentary castings resulting from differential compaction during diagenesis.

In thin section the upper Ravalli sediments east of Fortine Creek road are seen to consist of about 70 percent silt and 30 percent clay. A small percentage of very fine sand occurs in the basal part of microscopically graded laminae. These graded laminae pass upward into medium silt. By Folk's terminology (1961), the textural name for these sediments is very fine sandy mudstone. Included in these graded sequences are scattered rounded intraformational pebbles of clay-size material, similar in general appearance to the clay beneath the graded sequence. These pebbles, along with mica flakes and a few quartz grains, seem to be imbricated and to indicate thereby a southeastward direction of movement of the transporting medium, possibly offshore currents. Few thin sections were available for examination, however.

The total size range of these sediments is clay to fine sand (0.21 mm). Sorting is poor, and the textural maturity is immature. The mean size of the silt is medium silt. The abundance of clay and medium silt results in a bimodal size distribution in these sedimentary rocks.

Quartz, which constitutes more than 90 percent of the sand and silt grains, is mostly common quartz (Folk, 1961) and occurs as single grains or as parts of rare composite grains. Extinction is straight to slightly undulose (Folk, 1961). Scattered stretched metamorphic grains (less than 2 percent) were seen in most of the thin sections.

Some of the subangular composite grains contain well-rounded grains of quartz. These grains indicate that the composite grain was derived from a pre-Ravalli sedimentary rock in which quartz grains had been cemented by quartz cement. Subsequent erosion of the sedimentary rock produced the subangular composite grains deposited in the Ravalli.

Feldspar, mainly plagioclase, constitutes less than 5 percent of the sand and silt. Although evidence is not conclusive, the distribution of clay minerals around the feldspar grains indicates that the feldspars were altered in place. Quartz grains surrounding the feldspar are in point contact with other quartz grains without clay particles between, but a coating of clay separates feldspar grains from quartz grains. Some of the black and green biotite found in the sand and silt fractions is probably detrital.

For rocks in the southwest part of the SW Stryker quadrangle the term Ravalli Group undifferentiated as adopted by Calkins (1909) is used, although in a future detailed stratigraphic study a three-fold division of the Ravalli Group in this area may be feasible. The environment of deposition for much of this section seems to have been uniform, as the rocks are fairly homogeneous, hence the Ravalli Group designation is best suited for this area. This usage is in accord with Johns (1960-62), Gibson and others (1941), Shelden (1961), and Hall (1962), who have mapped west and south of the present map area.

The upper part of the Ravalli Group in the Rocky Mountain Trench area along the northeastern side of the Salish Mountains differs lithologically from equivalent rocks of the southwest corner of the SW Stryker quadrangle. Only the upper 1,500 feet of the Ravalli Group is found in the trench area south of U.S. Highway 93. In both areas the Ravalli Group is overlain by a series of greenish-gray dolomitic argillite beds. The exact thickness of the upper part of the Ravalli is difficult to determine, because of the many small faults, poor accessibility, and thick vegetation. Except in the northern part of the trench, near the town of Stryker, the boundary between the Ravalli Group and the Piegan Group is a fault contact.

Undifferentiated Ravalli rocks in the Whitefish and Kalispell quadrangles west of the trench commonly consist of light-gray noncalcareous quartzite and argillite containing magnetite and sparse to moderate amounts of biotite, but purple-gray banded quartzite predominates throughout the upper part.

From the junction of Wild Bill and Truman Creeks southeast to Blacktail Mountain (southwest corner of Kalispell quadrangle) narrow discontinuous streaks of red, purple, and pale-green argillite appear in predominantly gray noncalcareous argillite of the upper part of the Ravalli. Southeast of Blacktail Mountain the Ravalli lithology abruptly changes to a red-toned, dark-purplish-gray noncalcareous thin-bedded argillite containing mud chips and small limonite-filled voids through a thickness of several thousand feet below the Ravalli-Piegan contact. A graphically measured thickness of +7,400 feet was determined for the exposed part of the Ravalli Group from structural sections in the southwest Kalispell quadrangle. The base was not exposed in this area.

Ravalli strata in the north part of the Mission Range in the Somers quadrangle are thin-and medium-bedded medium-gray, light-gray, and purple-gray, red, and green-toned argillite interbedded with white fine- and medium-grained quartzite. Except for the occurrence of interbedded quartzite, these strata are similar to the upper part of the Ravalli at Blacktail Mountain.

The lowest exposed units in the Horse Plains quadrangle are greenish-gray and gray argillite, which grade upward into light-gray, purple-banded quartzite, which in turn grades into the purple-toned argillite below the Piegan Group. The upper two units are well exposed in Big Rock Creek. The thick quartzite unit separates the argillite units, giving the Ravalli Group a threefold differentiation of lithology, but the threefold division is somewhat obscured by numerous quartzite beds throughout the section. Because of the generally poor exposures and the reconnaissance nature of the study, the Ravalli Group was not divided into formations within the Horse Plains quadrangle.

The Ravalli-Piegan contact is gradational. The purplish-gray and greenish-gray argillite of the upper part of the Ravalli grade into greenish-gray and grayish-green banded argillite and calcareous argillite of the lower part of the Piegan Group. In the Horse Plains quadrangle map area, the contact was placed below the first calcareous argillite or limestone bed in the gradational zone. Although the base of the Ravalli is not exposed, the group is believed to be about 10,000 feet thick.

Piegan Group

The Piegan Group is divisible into three units, which can be traced throughout the map areas. The lower and upper units are composed mainly of green argillite and the middle unit of very calcareous and dolomitic argillite.

P_1 Unit.--The lower unit generally consists of light-greenish-gray and greenish-gray fine-grained argillite interlaminated with lesser very light gray coarse-grained argillite, which produces a banded appearance. Light-greenish-gray, greenish-white, and dusky-yellow coarse-grained argillite is interbedded with the finer grained argillite but makes up only a minor part of the unit. Many of the argillite layers are mud-cracked, and mud-chip breccias are common. In the lower third of the lower unit are a few beds of purplish-gray mud-cracked argillite interbedded with light-greenish-gray to greenish-gray mud-cracked argillite and mud-chip breccia. Minor thin beds of very light gray, light-gray, and greenish-gray medium- to coarse-grained, cross-laminated quartzite and quartzitic sandstone are present throughout the lower unit, but decrease in abundance toward the top. The unit is partly calcareous and dolomitic, the carbonate content increasing upward in the section. Weathering of the more calcareous laminae produces lenticular holes in outcrop. These holes are restricted to the lower and middle units of the Piegan Group and serve as one means of distinguishing the lower unit from other green argillite units, which are common in the Belt Series in the Stryker and Kintla quadrangles.

In summary, the lower Piegan represents a transitional unit between the underlying sandy and silty argillite and the overlying dolomitic and argillitic limestone. In the lower part, the change from Ravalli to Piegan is shown by a color change, a slight reduction in mean grain size, and an increase in dolomite and calcite, but the mineral composition and the sorting and shape of the grains are very similar. The decrease in stringers of rounded sand grains, general decrease in mean size of silt particles, decrease in mud cracks, and increase in carbonate, proceeding up section, may possibly indicate deposition somewhat farther offshore than the Grinnell sediments.

The lower Piegan unit P_1 observed in the Whitefish and Kalispell quadrangles includes medium-bedded and laminated medium- and light-gray commonly calcareous argillite, pale-yellow-green calcareous argillite, and greenish-gray laminated calcareous and noncalcareous silt-size argillite interbedded with a few thin gray limestone beds. Very thin layers of greenish and purplish-gray argillite, siliceous argillite, and light-gray quartzite are sparse. Some beds are brown toned, weather medium gray and orange brown, and are abundantly ripple marked and mud cracked. Leaching of calcareous material produces elongate cavities along bedding planes locally in the upper part of the unit. Limy oval nodules several inches long were noted in unweathered rock.

The lower part of the Piegan Group (P_1) is exposed near the Thompson River and consists of beds of pale-green to grayish-green, moderate-yellow-green, and some medium-gray argillite and calcareous argillite. Locally, thin beds of medium-gray fine crystalline limestone and thin beds of light-gray to white calcareous-cemented quartzite are present. The argillite is generally medium-banded pale green to dark yellowish green, and bedding ranges from laminated and locally fissile to medium bedded. Mud cracks are common, and the more sandy units are ripple marked. Sericite and cubes of pyrite occur in a few beds. The unit weathers to characteristic yellow-brown pebbles.

In thin section, the lower part of the basal Piegan is similar to the highest Ravalli in most respects. The sand layers differ only in that the mean size is somewhat smaller (0.25 mm). The sand is well sorted and supermature. The grains are subround to round and range in size from 0.1 to 0.5 mm (fine to medium sand). As in the Grinnell, the sand is interbedded with the clay and silt layers.

The fine-grained material consists of very fine to medium quartz silt, sericite, chlorite, and dolomite. The quartz silt is similar to that of the Grinnell in composition, size, and shape. Pyrite cubes and limonite pseudomorphs after pyrite in the basal unit are as much as 6 cm in width.

Ellipsoidal calcite segregations as much as 10 cm in length characterize the upper part of the basal unit. They are generally aligned parallel to the bedding, but in places lie at an angle to the bedding. Although all appear similar on first examination, they may have different origins. Some segregations are interpreted as of primary origin, because the enclosing laminae bend around the segregation. Others are interpreted as of secondary origin, because laminae can be traced through the segregation. The calcite segregations weather more rapidly than the surrounding dolomite and produce a deeply pitted surface, characteristic of the basal Piegan and the lower part of the central Piegan members. Weathering of the pyrite cubes and limonite pseudomorphs produces iron-stained, brownish surfaces, contrasting with the usual various shades of green.

Both symmetrical and asymmetrical ripple marks are present in this formation; their trend ranges from N. 30° W. to N. 10° E.; the most frequently observed direction is about N. 15° W., which parallels the shoreline of the marine Belt basin postulated by Fenton and Fenton (1937, p. 1939). Mud cracks occur in the lower part of the unit, but not in the upper part.

Beds of the basal Piegan are poorly exposed except in roadcuts or in places where glacial erosion has uncovered fresh bedrock. In several roadcut outcrops the basal Piegan has been altered to brown clay, and the calcareous material has been leached out, but original bedding is preserved. In the northwest part of the SW Stryker quadrangle, the unit contains more quartz silt, which forms well-exposed resistant ledges.

The contact with the overlying unit P_2 was placed above the pitted and nodule-bearing limestone beds in calcareous argillite and where the "molar-tooth" limestone becomes prevalent.

The thickness of the lower unit, P_1, measured near Werner Peak, was found to be approximately 1,400 feet. The contact with the middle unit is gradational and was placed where greenish-gray calcareous and dolomitic argillite without "molar-tooth" structure is overlain by light- to dark-gray argillaceous dolomite generally showing "molar-tooth" structure.

Outcrops of the basal Piegan unit form two parallel belts in the Stryker-Kintla map area (pl. 1). A wide belt of basal Piegan beds dipping gently west extends from the southern margin of the area northward to Dickey Lake in the east part. Vertical to overturned basal Piegan strata occupy the area east of the Brush Pass thrust fault in the southwest part of the area. These beds dip more gently to the north. The unit is more than 2,700 feet thick, as measured across outcrops where the beds are vertical. In the SE Stryker quadrangle the thickness seems to be about the same (pl. 1, cross sections).

The lower unit was determined to be 3,150 to 3,200 feet thick from structural sections near Blacktail Mountain. Incomplete sections measured graphically gave minimum thicknesses of 1,750 and 1,850 feet for this member, but a thickness between 1,250 and 1,500 feet was determined for the complete lower unit in Badrock Canyon on the Flathead River east of the Rocky Mountain Trench.

In the northern part of the Horse Plains quadrangle, units similar to other described lower and middle units of the Piegan Group crop out, but because of faulting, the thickness of the units could not be measured. A total thickness of about 8,000 feet for the Piegan was determined by Johns (1962b, p. 189) in the Thompson Lakes quadrangle northwest of this area.

P2 Unit.--The middle unit of the Piegan Group consists of interlaminated light-gray coarse-grained argillite and dark-gray fine-grained carbonaceous argillite, both of which are calcareous and dolomitic, and lesser amounts of very fine grained calcareous and dolomitic quartzite, which show cross-lamination on weathered surfaces. Light-gray stromatolitic limestone composed of the form-genus Collenia is especially abundant in the upper 1,000 feet of the middle unit and locally forms sequences as much as 40 feet thick. Occasional intraformational conglomerate consisting of light- to medium-gray discoidal limestone fragments in a matrix of light-brown-weathering calcareous and dolomitic sandstone is diagnostic of the unit. Ellipsoidal holes in outcrop surfaces similar to those found in the lower unit are porduced by differential weathering of calcite lenses. "Molar-tooth" structures are abundant in the middle unit and are formed by differential weathering of an intricately contorted system of calcite veinlets in a calcite-poor laminated argillite. Mud cracks are rare in the middle unit.

Limestone of the middle unit of the Piegan Group forms the highest peaks in the area and crops out extensively on the higher ridges and the steep-sided valleys. Because joint patterns are well developed, the middle Piegan generally appears blocky, but unbroken massive strata are also present. Weathered surfaces are yellow to brown, depending on the dolomite content. Rocks containing the most dolomitic argillite may locally have a weathered reddish-brown coating ranging from 2 to 30 mm in thickness.

In hand specimen the central Piegan unit consists of silty dolomitic argillite, argillitic dolomite, and limestone. The limestone layers are commonly bluish gray; the greenish-gray and olive-gray beds are generally more dolomitic. Stratification ranges from laminated to thick bedded.

As mentioned previously, calcite segregations are present in both the lower and middle units. In the middle Piegan unit these segregations are both perpendicular and parallel to bedding. Hall (1962, p. 34) presents an excellent discussion of these structures. Cubes and pockets of pyrite occur in the centers of the calcite segregations.

The "molar-tooth" structure as described by Daly (1912, p. 73) and by Fenton and Fenton (1937, p. 1926) is very rare and only tentatively identified in the SW Stryker map area. What is commonly called "poorly developed molar-tooth" by many geologists is widespread in the area. This type is believed to be of inorganic origin. The rocks have a fractured appearance, and the fractures seem to be filled with secondary calcite. Shelden (1961, p. 23) studied these structures in thin section and concluded that secondary calcite had filled the fractures, providing the veinlike patterns found in the middle Piegan limestone. He reported calcite fillings cutting across earlier fillings.

An interesting cycle of sedimentation is exposed in a roadcut in sec. 6, T. 32 N., R. 25 W. The first unit of this cycle is 3 feet of "poorly developed molar-tooth", which grades upward into about 3 feet of homogeneous dark-gray argillitic dolomite. Resting sharply on this unit is 2 to 4 inches of brecciated algal-like limestone and dolomite, overlain by a 4-foot bed of calcite segregations; the lower ones are parallel to bedding, but the upper ones are perpendicular to bedding. These perpendicular segregations grade into a second zone of "poorly developed molar-tooth" structure. Variations of this cycle, such as the absence of some units, were noted in other localities.

The transition from basal to central Piegan is marked by an increase in carbonate content and a color change from greenish gray to bluish gray. The two units are similar in the types of minerals present but differ in quantities. Again, as between the Ravalli and the basal Piegan, the boundary between these two units is arbitrary.

Within the Kalispell area (pl. 2 and 3) the middle unit is characterized by "molar-tooth" structures in thin- to medium-bedded and massive dark- through light-gray and light-yellow-brown dolomitic and argillaceous limestone, but includes minor amounts of medium-gray and gray-green banded argillite. The unit weathers gray and moderate yellow orange and brown.

In the few outcrops examined in the Horse Plains area, the unit is a medium-gray and light- to moderate-yellowish-brown "molar-tooth" limestone interbedded with greenish-gray argillite; the limestone weathers yellow brown and light gray. None of the stromatolites that cause the "molar-tooth" structure were identified.

In thin section the central unit is seen to be very similar to the basal unit, but it contains more dolomite and calcite and less clay. In some beds the carbonate content (dolomite and calcite) reaches 50 percent, but the quartz and feldspar silt content is generally about 70 percent. The silt is very fine to medium, angular to subangular. X-ray diffraction examination showed no basic changes in mineralogy from that of the basal unit.

Northwest of Flathead Lake an incomplete sequence 5,800 feet thick was measured from a structural section. The top of the middle unit is an erosion surface in this area. The exposures of the unit in the east Stryker and Kintla quadrangles were insufficient for section measurement, but graphical estimates at South Coal and Big Creeks gave 4,600 and 5,800 feet respectively. The contact with the upper unit is gradational but fairly abrupt, lying within a section less than 100 feet thick. The middle Piegan unit is the most widespread lithologic unit in the SW Stryker map area and covers more than 125 square miles (pl. 1). It forms a belt 10 miles wide through the center of the area and extends from the southern end of the quadrangle to the Rocky Mountain Trench. Because upper Piegan rocks were not found in this area, no complete thickness could be determined for the middle Piegan. Maximum thickness determined by cross section (pl. 1, section) is about 4,500 feet. The unit is poorly exposed in the Horse Plains quadrangle and is found only along the extreme western edge of the area (pl. 4).

P_3 Unit.--The upper unit consists of pale-yellowish-green, yellow-greenish-gray, and pale-green fine-grained argillite interlaminated with pale-grayish-green to grayish-green, pale-greenish-gray to greenish-gray, and minor pale-yellowish-green and very light gray coarse-grained argillite, interbedded with dusky-red and grayish-red coarse- to fine-grained argillite. In the northern part of the map area, the reddish argillite is present only in the upper part of the unit, but it increases in abundance toward the southeast. Lamination in the argillite is generally parallel, but some of the thicker coarse-grained argillite laminae are cross-laminated in very thin sets. Most of the argillite, especially the coarser, is calcareous.

In the northern part of the Whitefish map area, the upper unit of the Piegan Group is about 1,200 feet thick, but it thickens toward the southeast. It is about 1,800 feet thick near Moose Lake and on Standard Peak. The top of the upper unit is arbitrarily placed at the base of the overlying Purcell lava. South of the wedge-edge of the lava, the contact between the Piegan Group and Shepard Formation seems to be transitional and is difficult to establish.

The only other exposure of the upper Piegan unit throughout other map areas is in the northeast corner of the Columbia Falls quadrangle, where the unit is estimated to be 1,800 to 2,000 feet thick.

Missoula Group

The Missoula Group is subdivided into four conformable formations overlying the Purcell Basalt. Missoula strata are present in the central and eastern parts of the Whitefish Mountains and between Lake Five and the Middle Fork Flathead River.

Purcell Basalt.--The Purcell lavas, named the Purcell Basalt (Wilmarth, 1938, p. 1746), are present only in the Whitefish Mountains, where they are thickest in the north-central part of the range. They are about 350 feet thick near Moran Peak, thin fairly uniformly toward the southeast, and are only 20 feet thick on Standard Peak, where a basal flow of chloritized pillow lava is overlain by amygdaloidal flows. The lavas are absent at the junction of Kimmerly and Canyon Creeks.

The occurrence and composition of the Purcell Basalt in the NE Ural quadrangle is described in detail by A.W. Shelden in a section of Montana Bureau of Mines and Geology Bulletin 23 published in 1961.

Shepard Formation.--In the Whitefish Mountains, the Shepard Formation consists of interbedded medium-light-gray cross-bedded calcareous and dolomitic quartzite and oolitic limestone and very pale orange stromatolitic dolomite, all of which weather grayish orange or pale yellowish orange, interbedded with grayish-green and gray dolomitic siltstone and argillite. Toward the southeast the siltstone and argillite increase at the expense of the quartzite and stromatolitic dolomite.

The thickness of the Shepard Formation is about 400 feet throughout its area of exposure in the southern part of the Whitefish Range. The lower boundary of the formation is the top of the Purcell Basalt where that formation is present, but where lavas are absent the boundary is arbitrarily placed where the grayish-green argillite of the upper unit of the Piegan Group grades upward into the pale-yellowish-orange-weathering dolomitic argillite of the Shepard Formation. The contact with the overlying Kintla Formation is also gradational.

Kintla Formation.--The term Kintla Formation is here used to include beds stratigraphically equivalent to the Kintla as originally defined by Willis (1902, p. 324) in the northwestern part of Glacier National Park.

The Kintla Formation of the map area consists of greenish-gray coarse-grained micaceous argillite or very fine grained sandstone and quartzite, partly parallel-laminated and partly cross-laminated in thin sets, interlaminated with grayish-red-purple fine-grained argillite. The upper part of the formation consists mainly of greenish-gray coarse-grained argillite, partly cross-laminated, containing interlaminated pale-red or yellowish-gray to very light brownish-gray fine-grained argillite. The fine-grained argillite is also commonly found as mud chips in the coarser-grained argillite. A few thin beds of medium-gray silty dolomite weathering grayish yellow orange are found in the uppermost part of the formation. In the lower part, thin dolomitic stromatolite beds interbedded with quartzite are found locally. The Kintla Formation is generally flaggy weathering, commonly splitting in the thinner grayish-red-purple fine-grained argillite interbeds, producing extensive talus sheets. Salt-crystal casts and molds are found throughout the formation and serve to distinguish the Kintla from similar formations such as the Snowslip. Current ripple marks are common in the Kintla Formation.

The Kintla Formation is about 2,900 to 3,300 feet thick throughout (pl. 1). The contact with the overlying Phillips Formation is generally sharp.

Phillips Formation.--The Phillips Formation consists of moderate-grayish-red to moderate-dusky-red very fine grained to fine-grained feldspathic sandstone and quartzite, containing interbedded moderate-grayish-red or moderate-dusky-red coarse-grained argillite and lesser amounts of grayish-pink and pale-red sandstone. Moderate-red mud chips are locally common. Medium to coarse rounded frosted sand grains, probably of eolian origin, are locally scattered along lamination planes, particularly in the lower part of the formation. Light-greenish-gray sandstone is found in the lower few feet of the formation in some areas. The Phillips quartzite and sandstone are commonly cross-bedded, and ripple marks and mud-crack casts are found in the interbedded argillite.

The thickness of the Phillips is almost uniform throughout the area of outcrop in the southern part of the Whitefish Mountains, ranging from about 650 to 700 feet. The upper contact is gradational into the overlying Roosville Formation through a thickness of a few tens of feet.

Roosville Formation.--The Roosville Formation is the uppermost Precambrian unit in the region and is widely exposed in the northeast part of the map area.

The formation consists of almost uniform parallel-laminated greenish-gray coarse-grained argillite, mostly noncalcareous. Light-greenish-gray fine-grained argillite is locally interbedded or interlaminated with the coarser argillite, and the coarser laminae commonly contain mud chips of light-greenish-gray, reddish-brown, pale-grayish-orange, and yellowish-orange fine-grained argillite. About 700 feet above the base is a 35-foot zone of dusky-red and dusky-red-purple coarse-grained argillite, some of which contains some very thin laminae of moderate-red fine-grained argillite. Thin interbeds of light-gray or medium-light-gray to greenish-gray fine- to medium-grained quartzite are found in the lower part of the formation. Thin beds of dolomitic stromatolites of the Collenia type, some of which are silicified, are found in the lower 1,000 feet.

The upper part of the Roosville Formation is faulted out and not exposed in the map area, and no information as to the nature of the Precambrian-Cambrian boundary is available. The minimum thickness of the Roosville exposed along Dead Horse Creek is about 4,000 feet.

CENOZOIC

Kishenehn Formation

The Kishenehn Formation underlies most of the valley of the North Fork Flathead River north of Glacier View Mountain, but because it is nonresistant and is extensively covered by Quaternary moraine, outwash, and alluvium, exposures are nearly limited to the bank of the river on the convex side of meanders, where the Quaternary cover is thin.

Only a small part of the formation is exposed, therefore the description given here may not be representative of the entire section. Most of the outcrops examined contain several different rock types interbedded with one another. The most common is a light-gray to very light gray, very fine grained sandstone or sandy siltstone that weathers light gray. It contains carbonized twigs and wood fragments, and some sand-size fragments of maroon and green Belt argillite. It is locally clayey and commonly calcareous. Pale-brown or brownish-gray fine- to medium-grained sandstone is also present. Moderate-reddish-brown silty and sandy calcareous claystone and dark-gray carbonaceous shale and lignite are interbedded with the siltstone and sandstone. The lignite is generally only a few inches thick, but two seams exposed along the Flathead River bank about a mile below the mouth of Coal Creek are 2 to 3 feet thick.

The Kishenehn lies unconformably on Belt Series rocks in the North Fork area. Exposures of the Kishenehn are insufficient to permit a reliable estimate of thickness, but the attitude of the beds and the width of their outcrops indicate that it amounts to several thousand feet, even allowing for repetitions due to normal faulting.

In the Horse Plains quadrangle, conglomerate and sandstone are poorly exposed, mainly in a narrow area at the base of overlying volcanic tuffs. They are not differentiated as separate units on plate 4. Poorly consolidated subangular to rounded pebbles and boulders of Ravalli argillite and quartzite in a matrix of quartz sand, clay, and sericite compose the light-gray to moderate-yellowish-brown conglomerate. Locally, soft light-gray quartz sandstone is present. Wood from decomposed trees found in shallow prospect pits owned by H.M. Connant (eastern part of sec. 26, T. 25 N., R. 23 W.) retains so little of the original texture that identification as to genus is impossible. Elsewhere fine-grained material contains plant impressions.

A conglomerate, at least 25 feet thick, underlies a cap of Quaternary terrace gravel in a logging-road cut south of Tamarack Creek ($SW\frac{1}{4}$ sec. 30, T. 26 N., R. 24 W.). The rounded argillite and quartzite boulders are in a soft clay-rich sandy matrix and are stained dark yellowish orange. There are interbeds as much as 6 inches thick of soft grayish-orange claystone, and a 2-inch tuff bed near the base of the exposure.

Several small streams (Clear, Tamarack, Redmond, Briggs) in the vicinity are underfit and occupy broad alluvial valleys, which are about 200 feet higher than the present valley of the Little Bitterroot River, indicating that the conglomerate was deposited when volcanic flows dammed Little Bitterroot River in Tertiary time. Later dissection by Tamarack Creek has exposed the conglomerate as a remnant of a filled Tertiary valley.

Glacial Deposits

Glacial deposits of Late Pleistocene age occur within the quadrangles mainly as surficial deposits within Flathead and Stillwater Valleys. Older-appearing Pleistocene drift is exposed locally along the North Fork Flathead and Flathead Rivers in the Columbia Falls quadrangle.

Deposits of direct glacial origin include constructional moraines, outwash deposits, and till composed of boulder clay, sand, and stratified and unstratified gravel. Boulders, cobbles, and pebbles can be recognized as being derived chiefly from sedimentary rocks of the Belt Series.

Deposits indirectly related to the Cordilleran ice sheet are nonindurated lacustrine sand, silt, varved clay, and ice-rafted boulders; the deposits are surficial and are variable in thickness. Erdmann (1944, p. 75) described a remnant of silt on the southeast side of Teakettle Mountain at a elevation of 4,250 feet, probably representing the uppermost stage of a lake in which silt was deposited within the valleys.

Glacial outwash gravels are present in both the Little Bitterroot Valley and the Thompson River valley and represent most of the alluvium on plate 4. Several gravel-capped terraces ranging up to 200 feet above the present river level are present in the Little Bitterroot Valley near Hubbart Reservoir. The outwash gravels on the terraces are more than 50 feet thick in places and overlie Tertiary volcanic tuffs.. The terrace levels were probably controlled by different stands of glacial Lake Missoula during the Late Pleistocene.

Thompson River valley is partly filled by glacial outwash, but is unterraced, because the ice lobe protected it from the influence of Lake Missoula. A large gravel-capped terrace at the mouth of Big Rock Creek, below the terminal moraine of this lobe, may have resulted from a high stand of glacial Lake Missoula, but more probably it is a pre-Wisconsin deposit. The low divide to the north of the terrace may be an Early Pleistocene channel for the Thompson River.

Thicknesses of lake-bed silt are variable within the valleys, as the amount removed by river and stream erosion is not uniform from place to place. In some localities only thin superficial silt covers thick deposits of glacial and glaciofluvial material. Several feet of lake beds, exposed in an irrigation ditch (sec. 23, T. 26 N., R. 23 W.), consist of moderate-yellowish-brown to light-gray bedded clay and sandy clay; some lignitized plant fragments were observed on bedding surfaces. Alden (1953, p. 124) stated that a thin dune-sand cover at several localities in Flathead Valley was deposited after recession of the ice and lowering of the lake occupying the valley.

Recent Alluvium

Alluvial deposits of unconsolidated gravel and sand derived in part from reworked glacial deposits border most rivers and streams. Areas of thick soil adjoining Flathead River between Columbia Falls and Flathead Lake may have been developed in large part by flooding and rechanneling of the Flathead River between these points.

VOLCANIC ROCKS

The igneous rocks have an areal extent of about 25 square miles (pl. 4) and consist of andesite and latite, andesitic tuff, and intrusive bodies of andesite, latite, quartz latite, and basalt. Igneous rock suites of this type fit into Turner and Verhoogen's classification (1960) as late orogenic eruptions that are confined to a continental environment, but the volcanic rocks are not part of an extensive igneous province. The nearest other Tertiary volcanic rocks are the Columbia River basalt flows (Miocene) in Idaho, which are 85 miles distant. Because the volcanic rocks are genetically related flows and intrusive bodies and are confined to an isolated area, they can be treated as a unit. The writer (Page) suggests the name "Hog Heaven volcanics" after Hog Heaven Hill east of the Flathead mine, which is in the Hog Heaven mining district.

The time of the volcanic activity is unknown, but probably it is late Tertiary or early Pleistocene. It is certainly pre-Wisconsin, as several glacial-outwash terraces are cut into the tuff near Hubbart Reservoir, and some erosion has occurred since the eruptions; Shenon and Taylor (1936, p. 21) estimate not more than 400 feet in the vicinity of the Flathead mine. No cones have been found, and the lack of continuity of the flows and tuffs suggests that only the thicker parts now remain, presumably where they have filled pre-volcanic valleys. Supporting this hypothesis is the presence of poorly sorted argillite conglomerate and quartz sandstone, which are probably stream deposits, under the volcanic rocks in many places. They are well exposed underground at the West Flathead mine (fig. 4) and the Sullivan Creek Spring drift (fig. 3).

The rocks have been named according to Johannsen's classification (1939) but were not delineated separately on plate 4 except for the basalt.

Porphyritic Andesite

At least three different kinds of porphyritic andesite occur in the map area--one finely porphyritic biotite andesite and two coarsely porphyritic andesites. The finely porphyritic rock caps hills near the Flathead mine (SW$\frac{1}{4}$ sec. 9, SW$\frac{1}{4}$ sec. 16, and center sec. 20, T. 25 N., R. 23 W.). It was described by Shenon and Taylor (1936, p. 12):

> "It is a dense brownish-gray rock which under the microscope shows well-defined flow structure. It contains plagioclase and biotite phenocrysts in a felted groundmass. The phenocrysts make up about 40 percent of the rock. Plagioclase with a composition of Ab_{70} constitutes about 80 percent of the phenocrysts, biotite about 15 percent, sanidine less than 5 percent, and magnetite about 1 percent. The plagioclase phenocrysts have a maximum length of about 1 millimeter and average about 0.02 millimeter. Titanite occurs as isolated grains. Rock of this type is generally relatively unaltered, although the biotite is slightly changed to a fibrous product and magnetite."

Accessory minerals include apatite and sphene.

The coarsely porphyritic andesites are biotite andesite and biotite-hornblende andesite. The biotite andesite is found north and west of the Flathead mine (sec. 8 and 17, T. 25 N., R. 23 W., and SW part of sec. 24, T. 25 N., R. 24 W.). It is a light-gray to grayish-blue moderately resistant rock. Phenocrysts are mainly euhedral to broken plagioclase crystals, oligoclase to andesine (ave. Ab_{65}) having a maximum length of 6 millimeters. They are commonly twinned and weakly zoned; some have potassium-rich rims around an andesine core. Other phenocrysts include euhedral biotite, embayed sanidine, and rounded quartz. The matrix, about 60 percent of the rock, is either devitrified glass or very fine crystalline trachytic feldspar and some quartz. Accessory minerals are zircon, apatite, iron ore, and sphene. In many places the rock shows flow structure of subparallel biotite and contains broken feldspar phenocrysts. The biotite andesite probably constitutes several separate flows.

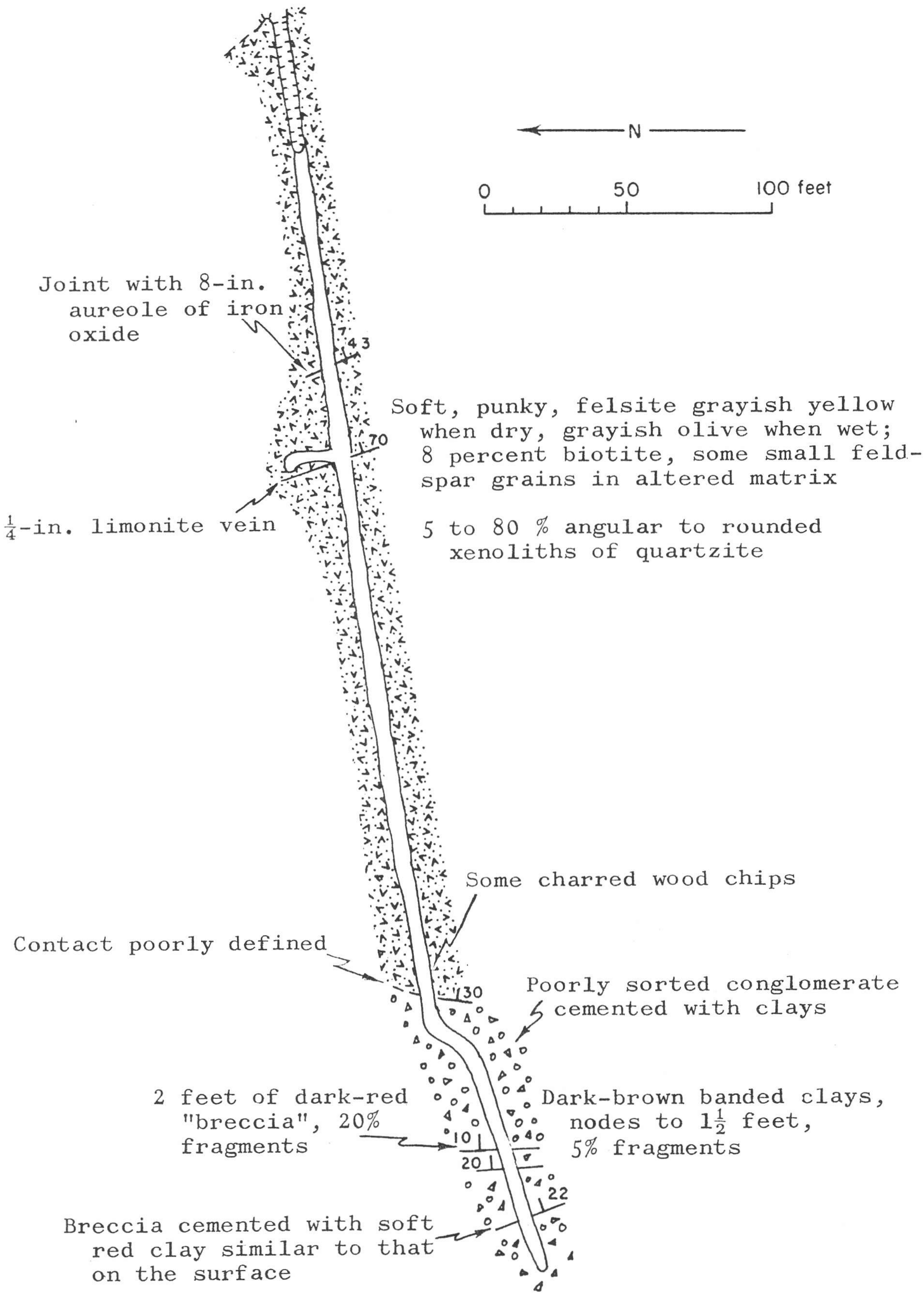

Figure 3.--Geologic map of Sullivan Creek Spring drift.

The biotite-hornblende andesite is a flow (or flows?) in sec. 19, 27, and 30, T. 25 N., R. 23 W., and sec. 35, T. 25 N., R. 24 W. The matrix is dark-gray and locally pale-brown flow-banded glass. The phenocrysts are similar to those in the biotite andesite but include some minor hornblende, which is partly altered to biotite and iron ore. Also, the plagioclase phenocrysts are more calcic and have a composition of andesine (ave. Ab_{60}), and some have a peculiar "honeycomb" structure. The feldspar has many rounded vermicular holes filled with glass, biotite, magnetite, and unidentified crystalline material. Kuno (1950) has described a similar structure in some of the plagioclase (oligoclase to andesine) from the Harkone volcanic rocks in Japan. He thinks that such feldspar is xenocrysts (foreign crystals from wall rock) that were out of equilibrium with the magma. Partial melting along cleavage cracks of the plagioclase was accompanied by diffusion of material into the crystal from the magma. The glass and crystalline material in holes seems to support this hypothesis. The source of the xenocrysts is unknown, but they may have come from another part of the crystallizing magma, from another magma, or from inclusions of wall rock. The rim of nonvermicular plagioclase implies that the plagioclase had reached equilibrium with the magma and had started to grow again just before extrusion.

Porphyritic latite

Porphyritic latite is found mainly in a small area around the Flathead mine (sec. 16, 17, and 21, T. 25 N., R. 23 W.) but is exposed in a prospect pit ($W\frac{1}{2}$ sec. 24, T. 25 N., R. 24 W.). The rock is generally altered but where fresh it is as Shenon and Taylor (1936, p. 9) describe:

> "The porphyritic latite where fresh is dark gray and has two distinct groups of phenocrysts in a microcrystalline groundmass. As an average the phenocrysts make up about 50 percent of the rock. The larger phenocrysts are glassy-appearing sanidine; the smaller ones are principally plagioclase with a composition of about Ab_{70}. Very few quartz phenocrysts were seen. Sparsely distributed microphenocrysts of biotite and magnetite are scattered through the groundmass, but together they constitute less than 5 percent of the rock. The microscope shows the presence of a highly altered pyroxene and a small amount of titanite. The groundmass is so fine-grained that it is impossible to distinguish all the minerals, even under high power. It is made up largely of tiny lath-shaped feldspar crystals but contains also very fine-grained quartz.
>
> "The sanidine phenocrysts range in length from about 0.5 centimeter to over 6 centimeters, and most

of them show well-developed carlsbad twinning. Many sanidine crystals exhibit distinct zoning. In general, the sanidine crystals have sharp boundaries, and none were observed to be broken. The plagioclase phenocrysts are generally less than 0.5 centimeter in length and usually show pronounced albite twinning. The outlines of these phenocrysts are generally sharp, but embayments are more common than in sanidine crystals."

Andesitic Tuffs

Most tuffs are andesitic and are generally a white to grayish-orange altered porous lightweight rock (for example, near Hubbart Reservoir, sec. 18, T. 25 N., R. 24 W., and east of Sullivan Creek Spring, sec. 26, 27, 28, 33, 34, and 35, T. 25 N., R. 23 W.).

Subangular to rounded fragments of argillite and quartzite are ubiquitous, but vary greatly in total amount, averaging 12 percent of the rock. "The fragments are more resistant than the enclosing material and hence weather out as prominent nodules on exposed surfaces, in many places causing the rock to resemble a conglomerate" (Shenon and Taylor, 1936, p. 13). The andesitic tuff contains broken fragments of plagioclase (andesine, Ab_{65}) (40 percent), euhedral, broken and flexed biotite (8 percent), and some sanidine and accessory zircon, iron ore, sphene, and apatite. The matrix is glass, which is generally altered to clay, but locally has been altered to chlorite, carbonate, epidote, and hematite.

An unaltered, greenish-gray, hard, dense crystal tuff, the crystalline fragments having the composition of latite, crops out in a road cut west of Little Meadow Creek (center of sec. 22, T. 25 N., R. 24 W.). Foliation strikes N. 20° W. and dips 12° SW. The tuff consists of 18 percent rounded to subangular argillite fragments, 20 percent devitrified glass matrix, 45 percent feldspar, and 15 percent biotite. Zoned plagioclase (andesine, Ab_{65}) slightly exceeds sanidine in quantity. The feldspars are angular and broken; the biotite is generally bent.

At least some of the tuffs are waterlaid. An altered crystal tuff of trachytic composition is well exposed in the Montana Sunset Quarry east of Little Bitterroot River. It consists of a hydrothermally banded but light-colored rock having graded bedding (strikes N. 35° W., dips 34° NE.). The rock is composed of angular fragments of sanidine and some magnetite, zircon, and spinel, imbedded in a clay matrix. Also present are rounded and subrounded fragments of quartzite and argillite.

A tuff of a completely different character is exposed south of Tamarack Creek in a poorly consolidated boulder conglomerate. The 2-inch bed of soft, punky, altered tuff near the base of the exposure consists of broken, zoned sanidine, subrounded quartz grains, and broken and bent biotite. The matrix is mostly clay but includes some carbonaceous material.

Porphyritic Quartz Latite

This rock crops out west of Brooks Creek (sec. 9, 10, 15, and 16, T. 25 N., R. 24 W.) and is light to medium gray, hard, and dense. It consists of about 50 percent subhedral phenocrysts, 80 percent of which are plagioclase (andesine, Ab_{65}); 12 percent biotite; 8 percent rounded, resorbed quartz, and some sanidine. The matrix is finely crystalline, granular or saccharoidal in texture, and consists mainly of potassium feldspar and some plagioclase and quartz. Accessory minerals include sphene, iron ores, apatite, and zircon. Locally the rock has been silicified, and the fractures have been filled with small quartz veins.

Porphyritic Basalt

The basalt is altered, but is hard, dense, and black, weathering into small rounded, dark-yellowish-brown boulders. Two steeply dipping dikes crop out west of Hubbart Reservoir (sec. 11, 12, and 13, T. 25 N., R. 25 W.) and trend N. 46° W., but the eastern part of the eastern dike in sec. 12 and 13 changes to a flow(?) containing numerous amygdules of quartz and probably zeolites. The basalt is porphyritic, but the phenocrysts are completely replaced by epidote, chlorite, and magnetite. The matrix, about 60 percent of the rock, consists of subparallel plagioclase (labradorite), also partly replaced by these minerals.

Relationships of Intrusions and Extrusions

Most of the volcanic rocks are flows, but intrusive rocks have been found at several localities. Definite intrusive relationships are disclosed in the underground workings at the West Flathead mine (fig. 4). There a fine-grained, punky, altered "felsite" (andesite?) is in sharp contact with warped argillite of the Ravalli Group, and small dikes from the "felsite" cut the argillite. In the center drift of the mine, relationships indicate that the andesite intrudes porphyritic latite. The Ole mine (fig. 5) also exposes a dike-like body that cuts rocks of the Ravalli Group.

In an intrusive body exposed near the Martin mine west of Sullivan Creek (SW¼ sec. 20, T. 25 N., R. 23 W.) a bulldozer cut exposes the top of a small "felsite" plug, which intrudes a brecciated and faulted zone in Ravalli argillite.

Where a possibly intrusive body occurs west of Brooks Creek (NW¼ sec. 15, T. 25 N., R. 24 W.) the contacts are not exposed, but thin sections show the rock to be coarser grained and of a different composition (quartz latite) than other rocks of the volcanic suite. Perhaps the rock is a plug or sill that has cooled slowly, resulting in a coarser grain size and saccharoidal texture.

The porphyritic latite that Shenon and Taylor (1936, p. 9) regarded as a possibly intrusive body near the Flathead mine is at least in part a flow, as tree trunks have been found within this rock in the mine, but the Anaconda Mining Company underground maps show dikes and sills in the deeper workings.

Some of the contacts between Ravalli and volcanic rocks are fault contacts that postdate solidification of the igneous rocks, thus obscuring the relationships. Sullivan Creek Spring drift shows the relationships best (fig. 3). The drift is in altered crystal andesitic tuff that contains numerous angular to subrounded fragments of quartzite and argillite and some carbonized wood. The tuff overlies a conglomerate but near the end of the tunnel there is extensive alteration and shearing. The surface exposure shows argillite of the Ravalli Group in brecciated contact with the tuff. The surface breccia zone can be traced southward into sheared argillite. Thin sections of the breccia from several localities show that quartzite fragments are cemented with clay, not fine-grained igneous rock as would be expected if it were an intrusive contact. In addition, the poorly sorted Tertiary conglomerate that underlies the flow commonly resembles breccia that can be confused with intrusive-contact structures.

Intrusive bodies are only a small percentage of the total igneous rock in the area. Most igneous rocks are extrusive. The exact sequence of eruptions and flows and tuffs has been only partly determined. The altered andesitic tuffs are the most extensive igneous rocks and seem to be products of the first eruptions. Shenon and Taylor (1936, p. 13) stated that the numerous rounded argillite fragments in the tuffs point to a waterlaid origin for the tuffs, but the poor sorting and even distribution of the argillite fragments and the large areal extent of similar crystal tuffs is more likely the result of a nuée ardente eruption whereby a hot density-current of volcanic material incorporated loose argillite pebbles from the old land surface and distributed them throughout the flow.

The tuffs overlie Tertiary conglomerate and are the most extensively altered of the flows. The tuffs in turn are overlain by the coarsely porphyritic biotite andesite and the porphyritic latite flows. These flows are more altered and presumably older than the fresh glassy hornblende-biotite andesite flow. The youngest volcanic rock is the unaltered fine-grained andesite that caps some of the hills around the Flathead mine and overlies a tuff at Battle Butte and the porphyritic latite southeast of the Flathead mine.

The relationship of the basalt to the other igneous rocks is unknown, but the basalt certainly postdates the andesitic tuff, as it either cuts or caps it.

STRUCTURAL GEOLOGY

SEDIMENTARY ROCK STRUCTURE

The Whitefish Range is a tilted fault-block mountain range lying between the Rocky Mountain Trench and the North Fork Valley, both of which are faulted half-grabens. Two separate periods of deformation produced the present structural configuration of the range--Laramide folding and later normal faulting.

Laramide folding is nearly restricted to the southwest half of the map area (pl. 1) and produced open folds that are mostly broad and gentle. In the north-central part of the area stronger folding produced northeast asymmetry and local overturning of beds, particularly in the middle unit of the Piegan Group. Local westward asymmetry is found in an anticline that parallels Whitefish Creek on the east, but minor folds within the anticline have nearly vertical axial planes. The axis of one such fold east of Upper Whitefish Lake plunges about 20° NW., probably indicating the plunge of the major structure.

The general northwest structural trend in the Stryker quadrangle west of U.S. Highway 93 is shown by five major anticlines and synclines (pl. 1). Two minor folds are located in the northern part of the map area.

The principal folds are in the western and southern parts of the SW Stryker quadrangle. The most southwesterly fold, a northwest extension of the Elk Mountain anticline (Hall, 1962) is a northwestward-plunging asymmetrical anticline (pl. 1). Dips on its west limb range from 10 to 20 degrees, those on the east limb from 60 to slightly overturned. Johns (1962a) reported that this fold extends into the SE Pleasant Valley quadrangle. Ravalli rocks crop out along the crest, but on the eastern limb, both Ravalli and Piegan rocks are exposed.

Parallel to the Elk Mountain anticline and adjacent to it on the east is the northern extension of the asymmetrical Ingalls syncline (Hall, 1962), the eastern limb of the Elk Mountain anticline merging into the west limb of the Ingalls syncline. Its trend of N. 25° W. continues from the Pleasant Valley NW quadrangle. The dip of the east limb of the syncline is 5 to 15 degrees. Johns (1962a) has traced this fold in the NE and SE Pleasant Valley quadrangles, indicating a total length of about 30 miles. Piegan rocks occupy the trough of the syncline.

A gentle symmetrical anticline about 10 miles long lying to the east of the Ingalls syncline plunges northwestward and trends N. 20° W. to N. 35° W. Piegan rocks are at the surface over the anticline. This structure extends southward into the Pleasant Valley NW quadrangle and dies out northward in the vicinity of Beaver Creek.

Nearly parallel to the anticline just described and adjacent to it on the east is an asymmetrical syncline approximately 10 miles long. Dips on the east limb range from 5 to 25 degrees and the trend is N. 15° W. to N. 30° W.; its trough exposes only middle Piegan strata.

An asymmetrical anticline extends into the area from the south along Gergen Creek, through Grouse Mountain, and across Martin Creek, and dies out south of Sunday Creek. This fold is named the Grouse Mountain anticline (pl. 1). On the western limb, dips range from 10 to 25 degrees; on the eastern limb, to a maximum of 20 degrees. Rocks of the middle Piegan unit cover the flanks and most of the axial region of the fold. In the canyon walls along Martin Creek, basal Piegan rocks are exposed in the core of the anticline. The attitude of the beds is horizontal in the roadcut on Sunday Creek road. This fold was traced for 6 miles in the SW and SE Stryker quadrangles and may be the northern extension of the easternmost anticline of Johns (1962a, pl. 1).

A doubly plunging anticline, approximately 6 miles long, extends along the western margin of the Rocky Mountain Trench in the vicinity of Sunday Creek (pl. 1). Northwestward the axis of the anticline crosses into the trench and disappears under the glacial cover. This structure is named the Jumbo Lake anticline. The trend of the fold is N. 30° W., and dips on the limbs range from 5 to 15 degrees. The contact zone between the basal Piegan unit and the underlying Grinnell Formation is exposed in the railroad cuts along the Great Northern Railway tracks southeast of Dickey Lake in the plunging nose of the anticline.

West of the Jumbo Lake anticline, strata dip westward under glacial deposits. At the head of Ivor Creek, beds dip northeast under glacial cover. These dips suggest the existence of a northwest-plunging syncline in the vicinity of Dudley Slough.

A relatively small symmetrical anticline was mapped north of Edna Creek. The axial trace of this structure crosses Ivor Creek a mile northwest of Edna Creek (pl. 1). The fold was traced approximately $1\frac{1}{2}$ miles and has a northwest trend.

In the Kalispell quadrangle (pl. 3) a northwest-trending northwest-plunging anticline and syncline are slightly asymmetrical to the northeast. On the anticline Ravalli rocks are exposed, whereas the middle unit of the Piegan (P_2) is exposed in the synclinal trough. The lower Piegan unit, P_1, is repeated on the flanks of the syncline. The west limb and crest of a south-plunging anticline trend northwest along the west side of the trench into the southwest corner of the Whitefish quadrangle (pl. 2).

Sedimentary rocks throughout other areas of plates 2 and 3 have gentle to moderate easterly dips except where steeper bedding attitudes result from drag folding along faults.

Folds in the northern Horse Plains quadrangle are gentle, as are most folds in the Belt Series of northwest Montana. The structure in the map area is a broad, poorly defined anticline or anticlinorium. Rocks of the Ravalli Group dip gently westward throughout most of the area, but the Piegan Group, which overlies the Ravalli, dips 30° W. at the western edge of the area, and east of the area it dips gently to the east.

Minor folds are gentle and discontinuous, and they generally trend and plunge southward. The folds are not as pronounced as those farther north. In the Pleasant Valley quadrangle, for example, Johns (1962a, p. 17) reports that the Little Bitterroot anticline is a tight fold, asymmetrical to the east, but in the Horse Plains map area (pl. 4) it is only weakly expressed and dies out southward. Faulting has offset the folds, and tracing of individual structures is difficult.

FAULTS

Description of Faults

Two master faults, the Swan and Flathead, may be traced for long distances in northwest Montana. The Swan fault enters the Whitefish map area from the south along the valley of Whitefish Creek and splits into two branches south of Upper Whitefish Lake. The west branch follows the valley of the West Fork of Whitefish Creek to a point about a mile northwest of Upper Whitefish Lake where it again splits. The second master fault, the Flathead fault, enters the map area at Big Creek ranger station near the junction of Big Creek and the North Fork Flathead River and can be traced northwest to Cyclone Lake, where it splits into two parts.

Both the Swan and Flathead faults have large displacements. Near Upper Whitefish Lake, the stratigraphic throw on the Swan fault is of the order of 11,000 feet. Where the Flathead fault crosses Coal Creek about 3 miles southeast of Cyclone Lake its stratigraphic throw exceeds 10,000 feet. Other faults in the map area, although subsidiary to the Swan and Flathead faults, may also have large displacements. One such fault, along Stryker Ridge in the southwest part of the area, has a maximum displacement of about 4,500 feet. East of Stryker Lake the fault that forms the east boundary of the Rocky Mountain Trench has a stratigraphic throw of about 4,000 feet. The other faults that diverge from the Flathead and Swan faults are smaller, but displacement may be as much as a few thousand feet.

Three types of faults were mapped in the west part of the Stryker quadrangle. The largest faults are three longitudinal high-angle thrust faults. Also impressive are longitudinal normal faults concentrated in the Rocky Mountain Trench area. Two transverse normal faults are located in the northern part of the area.

The Brush Pass thrust fault has the largest displacement of any fault in the map area (Hall, 1962, p. 41); a 6-mile segment of this fault cuts through the southwest corner of the Stryker quadrangle. This fault has been traced from Little Bitterroot Lake (Johns, 1962a) in the Pleasant Valley SE quadrangle northward through the Ural quadrangle (Johns, 1961; 1962a), a distance of at least 70 miles. The northern extension of this fault is called the Gut Creek-Pinkham Creek fault. Johns (1961, p. 29) has reported a stratigraphic throw of 7,000 feet in the Ural quadrangle, where Prichard rocks have been thrust against Piegan rocks. The fault strikes N. 20° W. to N. 30° W. The main evidence for the dip of the fault is the asymmetry of the associated Elk Mountain anticline and Ingalls syncline. South of the Stryker SW quadrangle, Hall (1962, p. 42) reports a disturbed zone dipping 70 to 75 degrees. Stratigraphic throw in the Whitefish area could not be determined, because rocks of the Ravalli Group are found on both sides of the structure. The throw could be as great as 7,000 feet and still produce the mapped relationship.

A thrust fault of less magnitude, the Dunsire thrust (Hall, 1962, p. 42, pl. 1), extending northward from Hall's area was mapped 2 miles east of the Brush Pass thrust (pl. 1), but it seems to die out before it reaches Fortine Creek. Strata west of the fault dip vertically and beds east of the fault are nearly horizontal. The fault zone is characterized by fractured rocks and irregularly dipping blocks of strata. Middle Piegan rocks are exposed on both sides of the fault, and exact displacement could not be calculated. The apparent stratigraphic throw is between 500 and 1,000 feet in the Skillet Creek area.

The third thrust fault, in the Stryker SE quadrangle, is along Martin Creek, for which the structure is named in this report. The Martin Creek thrust begins in the southeast corner of the map area as a longitudinal fault and gradually changes into a transverse fault south of Ketowke Mountain. Strata on the north side of Martin Creek were dragged upward near the fault. The dip of these beds increases from 20° about a quarter of a mile northeast of the fault to nearly 60° adjacent to the fault trace. The west side has moved up in relation to the downthrown east side. This fault is in basal Piegan strata along Martin Creek and middle Piegan strata south of Ketowke Mountain. The trace of the fault ranges from N. 30° W. to N. 70° W. within a distance of 8 miles. This fault is not present in the Sunday Creek area.

Except for the Martin Creek thrust, most of the faults in the vicinity of the Rocky Mountain Trench have displacements characteristic of normal faults. These faults form horsts and grabens in the trench proper. The main difficulty in correctly interpreting these faults is that the exposed strata consist of several hundred feet of interbedded purplish and green argillite belonging to the upper part of the Grinnell Formation and the lower part of the basal Piegan unit.

In isolated small hills in the trench floor, exposures are too limited stratigraphically to permit recognition of the arbitrary Grinnell-Piegan boundary. Detailed stratigraphic studies are needed to establish parameters for distinguishing the various minor lithologic units in the trench so that the small faults could be mapped.

The principal normal fault in the Stryker area extends from the glacial deposits in the southeast to the glacial deposits in the northwest (pl. 1). Ravalli rocks on the east side have been faulted against basal Piegan strata on the west. The fault trace, trending N. 35° W., is easily seen on aerial photographs. The amount of displacement along the fault decreases northwestward (pl. 1). The west side of the fault has moved down in relation to the east side, as is characteristic of faults in the Whitefish Range on the east side of the Rocky Mountain Trench.

Two faults just southwest of the Martin Creek thrust and northeast of the principal thrust faults (pl. 1) are normal faults forming a graben. Displacement of the block is greatest in the southeastern part and diminishes northwestward, becoming negligible. The traces of the faults form straight lines regardless of topography, hence their dip must be nearly vertical.

Other small normal faults northeast of the main normal fault have displacements of tens of feet to several hundred feet. Only the two largest were included on the present map (pl. 1). These faults are readily discernible on aerial photographs and are easily verified by field investigation where accessible.

Two transverse faults that cut normal faults are present in the northern part of the Stryker area. Movement along the faults produced approximately 300 to 400 feet of stratigraphic throw. These faults cause basal Piegan strata to be displaced westward against rocks of the middle Piegan unit.

The strike of these faults is N. 75° W. The major normal fault on the southwest side of the trench is cut by these transverse faults in the vicinity of Jumbo Lake. Displacement is minor, but the transverse faults postdate the longitudinal faults, as shown by the abutment of different lithologies along the transverse fault traces.

Major faults in Flathead Valley and bordering areas (pl. 2 and 3) are northwest-striking structures of high angle, including both normal and reverse types. Only one low-angle fault plane (dipping about 30° W.) was observed; it occurs in a wide breccia zone in a cut on U.S. Highway 2 about half a mile southwest of Kila. A subsidiary group of vertical faults striking N. 65° E. displaces northwest faults.

That part of the Rocky Mountain Trench between Kalispell and Flathead Lake is a graben, that is, a depressed block bounded by normal faults. The structure of the trench between Kalispell and Whitefish is believed to be more complex, and some faulting probably is concealed beneath gravel and silt. On a diagonal line from the northeast corner to the southwest corner of the Whitefish quadrangle, all faults mapped are normal to the line and are either high-angle west-dipping or vertical ones, the west side having dropped down relative to the east side. This evidence verifies the observations of Barnes and Smith concerning the Rocky Mountain Trench in the Stryker quadrangle; this part of the trench is a faulted half graben.

The concealed Swan fault enters the southeast corner of the Somers quadrangle from Swan Lake Valley paralleling the western slope of the Swan Range to a point half a mile east of Lake Blaine, crosses the Flathead Valley $2\frac{1}{2}$ miles southwest of Columbia Falls, and follows the east shore of Whitefish Lake to the Stryker quadrangle. The fault is believed to be a high-angle west-dipping normal fault; stratigraphic throw in the Stryker quadrangle was found to exceed 10,000 feet.

Another partly concealed normal fault of large displacement parallels the east shore of Flathead Lake to merge with or displace(?) the Swan fault at a point a short distance west of Lake Blaine. Northwest of Bigfork, east-dipping lower Piegan rocks to the west adjoin east-dipping lower(?) Ravalli rocks east of the fault. The stratigraphic displacement was not determined, but it is less than 10,000 feet.

Six parallel northwest-striking high-angle or vertical faults traverse the Whitefish quadrangle but disappear beneath valley fill to the southeast. The faults are believed to be normal, the west side dropped relative to the east. The fault situated 2 miles northeast of Whitefish Lake is, on the south end of the Whitefish Mountains, a contact between east-dipping lower Piegan strata and upper Ravalli (Grinnell) strata, hence the stratigraphic throw is less than 4,000 feet. Another, parallel fault half a mile northeast of Whitefish Lake displaces the Ravalli-Piegan contact. Horizontal separation amounts to 1,050 feet. Two faults near Blanchard, Beaver, and Boyle Lakes and another structure parallel to Stillwater River (inferred from stratigraphic evidence) repeat the Piegan Group section across this part of the trench. The fault in Lost Creek drainage in the southwest corner of the Whitefish quadrangle was mapped on the basis of stratigraphic evidence and drag folding. This fault continues northwest along Lost Creek in the Pleasant Valley quadrangle and parallels the east shore of Talley Lake, where it marks the contact between the east-dipping middle Piegan unit to the west and the east-dipping lower Piegan unit east of the lake. At the mouth of Lost Creek, this fault forms the contact between lowest strata of the middle Piegan unit and the upper part of the Ravalli purple-gray banded quartzite. The stratigraphic throw exceeds 3,000 feet, as at this location the fault cuts out the lower Piegan unit.

Several faults trending northwestward were mapped in the Truman-Patrick area west of Flathead Lake in the Kalispell quadrangle. The largest fault was mapped from a point 2 miles north of Lakeside to west Kalispell; in part it follows the west side of Flathead Valley. The fault is a normal one, and where observed during relocation of U.S. Highway 93 in the W$\frac{1}{2}$ sec. 35, T. 27 N., R. 21 W., the gouge and breccia zone is 12 to 14 feet wide and dips 62° NE. Stratigraphic displacement was not determined, as no reliable marker beds were found within the two Piegan units, but in the valley in sec. 29 and 30, T. 28 N., R. 21 W., pyrite-bearing molar-tooth limestone outcrops of the middle Piegan unit are in near juxtaposition with lower Piegan strata west of the fault. A minimum stratigraphic throw of 800 feet is indicated, but displacement is probably much greater.

A fault inferred from topographic evidence and drag folding extends from Bierney Creek across the head of Patrick Creek to a position 1$\frac{1}{2}$ miles east of Smith Lake. Movement on the east-dipping(?) structure repeats middle Piegan strata.

Another fault of considerable length crosses a ridge three-quarters of a mile north of Blacktail Mountain and follows Truman Creek to U.S. Highway 2. In a roadcut half a mile southwest of Kila a sheared and brecciated zone several hundred feet wide contains two west-dipping strands, the western of which dips about 65°, the other approximately 30°. The reverse fault cuts out part of the lower Piegan unit.

A small fault striking slightly west of north and dipping 85° W. is exposed along U.S. Highway 93 one mile southwest of Somers. Vertical movement occurred within a 26-inch shattered zone.

Two transverse faults striking N. 65° E. were mapped in Trail Creek (southeast of Lake Blaine) and in the Teakettle Mountain area (3 miles northeast of Columbia Falls). A third near-parallel inferred fault, projected from the Nyack SW quadrangle to Echo Lake, may in part have caused the abrupt termination of the Mission Range north of Bigfork.

The Trail Creek fault and the inferred Echo Lake fault form a graben or depressed block occupied by basal and middle Piegan units; Ravalli strata cap the upthrown blocks.

The northeast-bearing vertical fault on Teakettle Mountain possibly continues up the Middle Fork Flathead River where it is concealed beneath alluvium. The north side is dropped relative to the south side. A probable fault in the northwest corner of the Columbia Falls quadrangle was inferred from the presence of shattering and shearing on each side of the drainage.

The numerous faults in the northern Horse Plains quadrangle fall into three categories, north-trending normal and reverse faults, east-trending wrench faults, and small faults associated with the volcanic rocks.

The oldest faults trend north. A normal fault of this type, exposed east of the Thompson River in a logging-road cut south of Big Rock Creek, is indicated by a zone of breccia and altered limestone at least 50 feet wide. Elsewhere, the fault is expressed as a linear fault-line scarp prominent on aerial photographs. The middle unit of the Piegan Group on the west side has been downthrown into contact with the lower unit of the Piegan on the east side, indicating a stratigraphic displacement of about 1,000 feet. This fault is probably a southeastward continuation of the Pine Creek-Thompson Lakes fault that Johns described (1960, p. 21). The Pine Creek-Thompson Lakes fault is a major fault; the west side is downthrown with respect to the east side, and the length is at least 40 miles.

Several other north-trending and probably steeply dipping normal faults were mapped. The displacement on these faults is unknown, but drag folds indicate that along many of them the west side has been downthrown with respect to the east side.

A reverse fault half a mile east of Thompson River in Murr Creek Canyon seems to dip steeply to the west. Ravalli blue-gray quartzite is faulted against middle or upper Piegan argillite, indicating a stratigraphic displacement of about 4,000 feet. The fault may trend north, but because of extensive glacial drift its true orientation and extent could not be discerned. The west side is upthrown with respect to the east side.

A large, high-angle wrench fault near Shroder Creek in the western part of the Horse Plains quadrangle is named the

Shroder Creek fault. It trends slightly north of west over much of its extent in the southwest part of the map area. The fault is exposed in a logging-road cut south of Shroder Creek near Thompson River, where it produced a minimum of 20 feet of bleached and punky limestone breccia. Elsewhere the fault is expressed topographically. In the Thompson River valley it is marked by a steep fault-line scarp, but eastward it changes direction and is expressed by linear creeks and low divides for 13 miles. The fault movement seems to be dominantly strike slip, the north side moving east and down with respect to the south side, as it offsets the north-south fault east of the Thompson River about $1\frac{1}{2}$ miles and the Piegan-Ravalli contact about 2 miles. A subparallel fault may be present farther north in the Briggs Creek valley.

Wrench faults postdate the normal faults. Major wrench faults in the region include the Osborn and Hope faults of Idaho and Montana, which strike slightly north of west. They show some vertical movement, but they are predominantly strike slip, the north side moving east with respect to the south. Movement on each of these faults is about 12 miles (Anderson, 1948). The Shroder Creek fault in the map area is similar in both trend and sense and is probably related to the east-trending fault set.

Considering the possibilities of ore deposits, the most significant faults are those that cut the volcanic rocks. The faults are irregular to linear, but many trend north. Where the faults bring Ravalli beds into contact with the volcanic rocks, the faults are invariably expressed as a yellow to red, iron oxide stained, porous breccia, in which angular fragments of quartzite are cemented with the clays. The breccia zone is commonly several feet wide, but much wider areas are hydrothermally altered and bleached. Faults that extend into the volcanic rocks are expressed as shear and fracture zones, but in the argillite and quartzite of the Ravalli Group they are expressed by drag folds, slaty cleavage, and bleached and altered areas. The direction and amount of movement of the faults are unknown.

A possible arcuate fault with a component of left-hand strike slip movement, present in Sullivan Creek near the Martin mine, has displaced the contacts about 500 feet, the west side having moved southward with respect to the east side.

The sequence of structural events in the northern Horse Plains quadrangle is essentially the same as elsewhere in northwest Montana. The north-trending fault east of the Thompson River has been offset by the west-trending Shroder Creek wrench fault. The emplacement of the volcanic rocks probably postdates major movement on the north-trending faults, as the volcanic rocks are not cut by a north-south fault that trends under them near Hubbart Reservoir. The relative age of the volcanic rocks with respect to the Shroder Creek fault is unknown. The volcanic rocks themselves are cut by faults that are possibly related to intrusion of a stock at depth, or to recurrent movement on pre-existing faults.

Summary of Faulting

Superimposed on the folds in the Belt Series of northwest Montana are normal and reverse faults. The dominant feature is the northwest-trending Rocky Mountain Trench. This topographic form is both a graben and half graben with vertical displacement measured in thousands of feet. The Swan fault, paralleling the eastern side of the trench, perhaps exerts the greater influence on the trend of this topographic feature.

West-trending transverse faults and wrench faults postdate northwest-striking normal faults where observed within the quadrangles. In the Horse Plains quadrangle the Shroder Creek fault is similar in both trend and sense to the west-striking Hope and Osborn faults of Idaho and Montana. These faults have some vertical movement but are predominantly strike slip, the north side having moved east with respect to the south. Movement on these faults is about 12 miles (Anderson, 1948). The Shroder Creek fault probably is related to this east-trending wrench fault set.

Many writers assign folding in the Belt Series to the late Cretaceous-early Tertiary Laramide orogeny. Some faulting is perhaps related to Laramide time, but undoubtedly major faulting has occurred during the Tertiary Period. Faulting in the Whitefish Mountains took place while the Kishenehn Formation was being deposited, and the Lewis thrust fault is late Eocene or early Oligocene and has been cut by north-trending block faults that have had sporadic movement throughout the Tertiary and Pleistocene (Mansfield, 1923, p. 269).

The emplacement of the volcanic rocks in the Hog Heaven district postdates major movement on the north-trending faults of the Horse Plains quadrangle, as the north-trending fault near Hubbart Reservoir and beneath the flows is earlier than the igneous rocks and does not cut them. The relative age of the volcanic rocks with respect to the Shroder Creek wrench fault is unknown. The volcanic rocks themselves are cut by faults possibly related to intrusion of a stock at depth, or to recurrent movement on pre-existing faults.

HYDROTHERMAL ALTERATION IN THE HORSE PLAINS QUADRANGLE

Extensive hydrothermal alteration and, locally, mineralization, is associated with the volcanic rocks but is structurally controlled by faults and fractures. The silicification and alteration of the porphyritic latite to clays and alunite at the Flathead mine has been described by Shenon and Taylor (1936, p. 9); elsewhere hydrothermal alteration is generally less intense. Bleaching and iron oxide staining is the most common alteration of both the volcanic and the Ravalli rocks. A tuff in the Montana Sunset building-stone quarry is banded pale yellowish orange and pale red. The banding is clearly related to a north-trending fault, the position of which, west of the quarry, is indicated by a porous iron oxide stained breccia.

Locally, hydrothermal alteration is intense, changing the rock completely to clay. A "thick-bedded" massive, dense, white claystone with slight iron oxide stain on the joints is exposed in the root cellar of the Jackson's old homestead (SW$\frac{1}{4}$ sec. 26, T. 25 N., R. 23 W.). The clay consists mostly of montmorillonite. The composition as analyzed by the Montana Bureau of Mines and Geology is 66 percent silica (SiO_2), 20 percent alumina (Al_2O_3), and 0.5 percent each of fluorine and calcium oxide.

Argillite and quartzite of the Ravalli Group are locally bleached or stained grayish orange to light brown for several hundred feet near the igneous bodies (S$\frac{1}{2}$ sec. 5 and NE$\frac{1}{4}$ sec. 8, T. 25 N., R. 23 W.). The argillite is commonly altered to soft white clay and sericite next to the contact with volcanic rock, but farther away the argillite is stained orange to brown. The alteration is probably related to faults. Elsewhere, for example, along faults that are several miles from exposed igneous rock, the Ravalli quartzite and argillite show bleaching and sericitization. An altered area related to a fault is well exposed west of Hubbart Reservoir where Ravalli quartzite has been altered to a soft, friable sandstone, containing quartz, white clay, and sericite. The width of the alteration zone exceeds 50 feet.

ORE DEPOSITS

In contrast to meager production from the other map areas, silver-lead production in the Hog Heaven mining district has been significant. Most mines of the district have made ore shipments, but the Flathead and West Flathead mines have accounted for nearly all the output; production amounts to 7 million ounces of silver, 4 thousand ounces of gold, 23 million pounds of lead, 600 thousand pounds of copper, and 5 thousand pounds of zinc (data summarized from U.S. Bureau of Mines Minerals Yearbook 1928-1953 and records of Anaconda Company).

The Ole, Martin, Birdseye, and Maryann mines were examined in a cursory manner, and the open workings mapped. These mines were discovered in the 1930's but have been only minor producers.

SILVER-LEAD REPLACEMENT DEPOSITS

The ore deposits in the Hog Heaven district are small, irregular, high-grade, silver-lead epithermal lodes. The Martin and Battle Butte mines have produced some copper, zinc, and lead; the Ole mine, some silver and gold. Tetrahedrite containing some silver was identified recently at the West Flathead property.

MANGANESE

A bog-type manganese deposit consisting of pyrolusite occurs in the Hog Heaven district of the Horse Plains quadrangle. The deposit does not seem to be extensive and is presently covered by water.

COPPER-BEARING QUARTZ VEINS

The copper-iron disulfide mineral chalcopyrite is spotty and scattered in small amounts in narrow quartz veins in the Whitefish, Kalispell, and Columbia Falls quadrangles. There has been only cursory exploration and little, if any, production from prospects located on these veins.

DESCRIPTION OF MINING PROPERTIES, NORTH HORSE PLAINS QUADRANGLE

Flathead Mine

The Flathead mine, discovered in 1928, has produced more than 90 percent of the ore in the district. Before closing in 1946 the workings were excavated to the 1,000-foot level. The writer (Page) was unable to examine much of the workings because of flooding and treacherous conditions. The mineralization in this mine is probably characteristic for the district, therefore the geologic relationships have been summarized from the underground maps of the Anaconda Mining Company and from Shenon and Taylor's report (1936) on the Hog Heaven mining district.

The workings near the surface are in volcanic flows and agglomerate, but the deeper drifts are in dikes and plugs that intrude both a "black, cherty argillite" and volcanic rocks. The ore body is in silicified, alunitized porphyritic latite and has a cellular structure resulting from leaching and replacement of feldspar phenocrysts. According to C.S. Foote, geologist for the Anaconda Mining Company, the ore body is shaped like an "inverted Mexican hat". The "brim" of the ore body is the zone of intense supergene enrichment; the "crown" is filled with veins and pods of primary ore showing some supergene enrichment. The main vein is irregular but nearly vertical and trends slightly west of north, bisecting the "crown" of the "hat". Where this vein intersects west-trending fractures and veins, the ore occurs in large pods. Nonetheless, the main ore body rakes steeply south.

The primary minerals are sulfides, mainly pyrite (FeS_2), galena (PbS), and antimonial matildite ($Ag_2S.Bi_2S_3$), but including some enargite ($3Cu_2S.As_2S$) and bornite (Cu_5FeS_4). The gangue is barite ($BaSO_4$), alunite $[(K,Na)_2O.3Al_2O_3.4SiO_3.6H_2O]$, quartz, and clay. Shenon and Taylor (1936, p. 17) show that there are two stages of mineralization:

> "Fine-grained quartz and pyrite were formed during the first stage. The rock was then fractured, and the fractures were healed, largely by very fine-grained quartz, barite, and sulphides . . . Galena is definitely later than the barite. It occurs commonly at the contacts of barite and quartz and, in some places, follows fractures in the barite. The matildite appears to be contemporaneous with the galena and is intimately intergrown with it."

Near the surface and generally in the "brim" of the "inverted Mexican hat", supergene enrichment has been extensive. Argentite (Ag_2S) and marcasite (FeS_2) are the most common minerals in this zone, but covellite (CuS) is also present. These supergene sulfides almost completely replace the hypogene sulfides, making rich ore. Also present near the ore bodies are sulfate oxidation products: ubiquitous beudantite (an arsenate or phosphate with sulfate of ferric iron, lead, and bismuth) and sparse amounts of anglesite ($PbSO_4$), siderotile ($FeSO_4.5H_2O$), melanterite $[(Zn,Cu,Fe)SO_4.7H_2O]$, and malachite ($CuCO_3.Cu(OH)_2$). The beudantite is a yellow clay mineral, which was X-rayed and identified by Dr. Russell Honea of the University of Colorado.

Solution holes or tubes several feet in diameter and tens of feet long are present above the 1,000-foot level. They contain "fumarole mud" (iron-rich beidellite) and commonly barite and alunite. Shenon and Taylor (1936, p. 21) stated that these minerals are primary, perhaps resulting from fumarole or hot-spring activity in the volcanic rocks.

Rich ore is still present in the deeper parts of the mines but in pods and lenses smaller than those in the upper workings.

West Flathead Mine

The West Flathead mine has produced about 220,000 ounces of silver. Discovered about 1941 by the Anaconda Mining Company, it has since been operated intermittently. The workings are shallow and are confined to the supergene enrichment zone.

The ore bodies occur in argillite of the Ravalli Group, adjacent to an altered porphyritic andesite plug. The ore is argentite, which occurs in "beidellite mud". The clay-rich mud fills smooth, rounded tubes and solution holes in the argillite that probably resulted from fumarole leaching and subsequent mineralization, hence the tubes are called "fumarole holes" by the miners in the area. The tubes differ in size, the largest being about 6 feet in diameter and at least 200 feet long. They generally lie in bedding planes, but tabular "fumarole holes" occupy joints in the argillite. Mineralization and alteration in the argillite is confined to the tubes and to a narrow zone of several inches in adjacent rock.

Ore is sparse in the igneous rocks of the mine, in striking contrast to the Flathead mine. Low-grade mineralization at the West Flathead, however, is most extensive in the igneous rocks, pyrite and other sulfides occurring extensively in portions of the andesite. The disseminated mineralization is intense around joints and fractures, making small veins and pods where fractures intersect. Waino's drift follows one of these veins (fig. 4). The vein is irregular and "poddy" and consists mainly of "beidellite", beudantite, barite, alunite, and some argentite. Primary sulfides (pyrite, argentite, bismuthinite(?), etc.) in an alunite matrix are found below the water table in the lower workings and winze.

At least two types of igneous rock are present. An altered porphyritic latite intruded by porphyritic andesite occurs near the portal of the center drift. The latite, similar to that near the Flathead mine, is probably related to that body, and the andesite is probably the same body that intrudes the argillite in the main drift of the West Flathead mine. Extrusive andesite, which may be part of the same body or from a different source, overlies the coal-bearing conglomerate in the main drift.

More "fumarole holes" are probably present northwest of the present mine workings, as the ore pipes already mined are oriented en echelon in that direction. Ore is also likely to be found at vein and fracture intersections in the igneous rock, as is common in the adjacent Flathead mine.

Ole Mine

The writer (Page) confirms Shenon and Taylor's work (1936) on the Ole mine. The mine consists of exploratory drifts and shafts (fig. 5) in an altered porphyritic latite(?) dike that has intruded argillite of the Ravalli Group. Supergene argentite mineralization in the porphyritic latite has associations similar to that of the Flathead and West Flathead mines. Pyrite, barite, beudantite, and some alunite occur in veins and as disseminated ore near silicified, cellular latite, but the argillite has been only slightly altered. It is silicified near

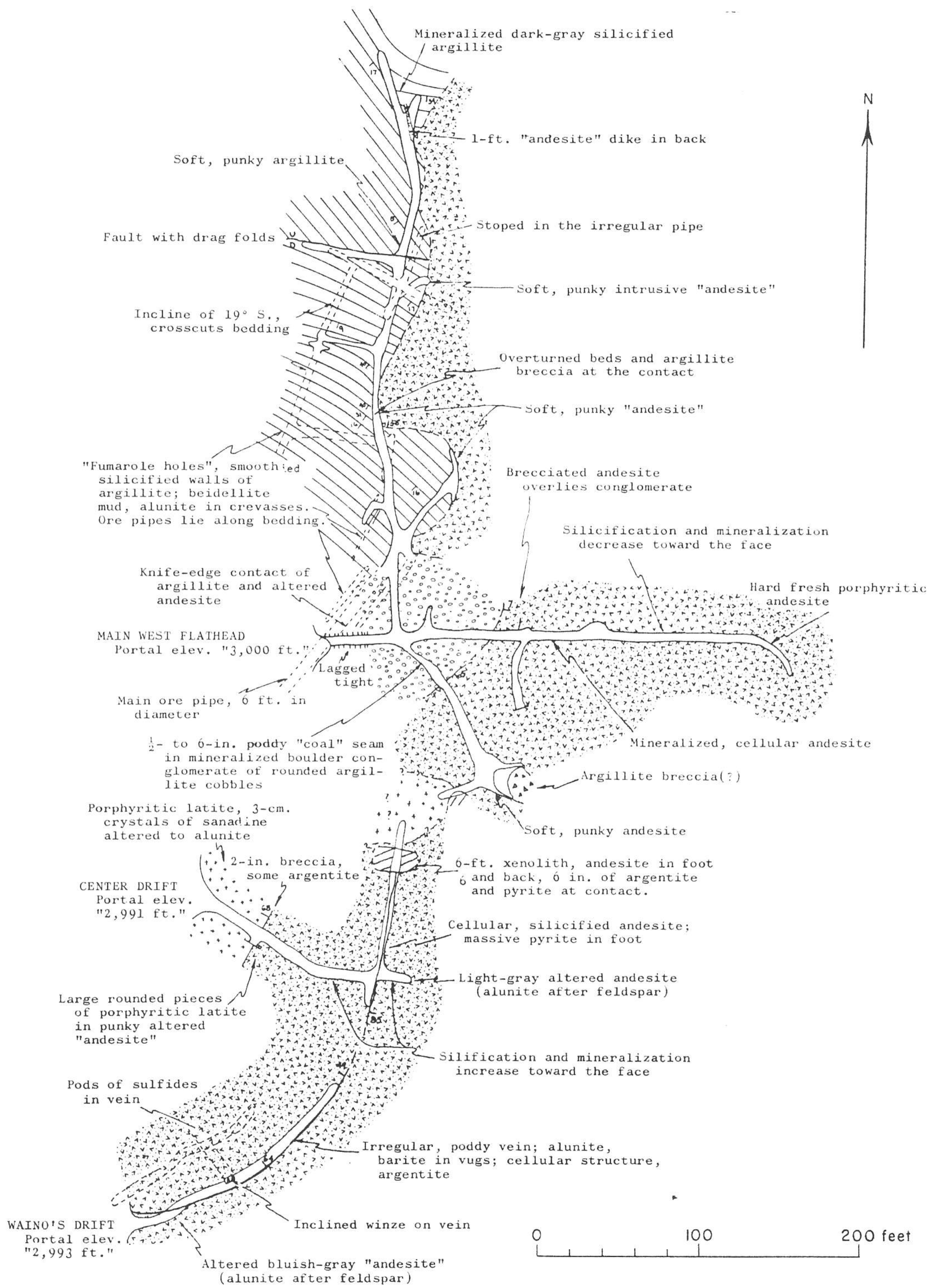

Figure 4.--Geologic map of West Flathead mine.

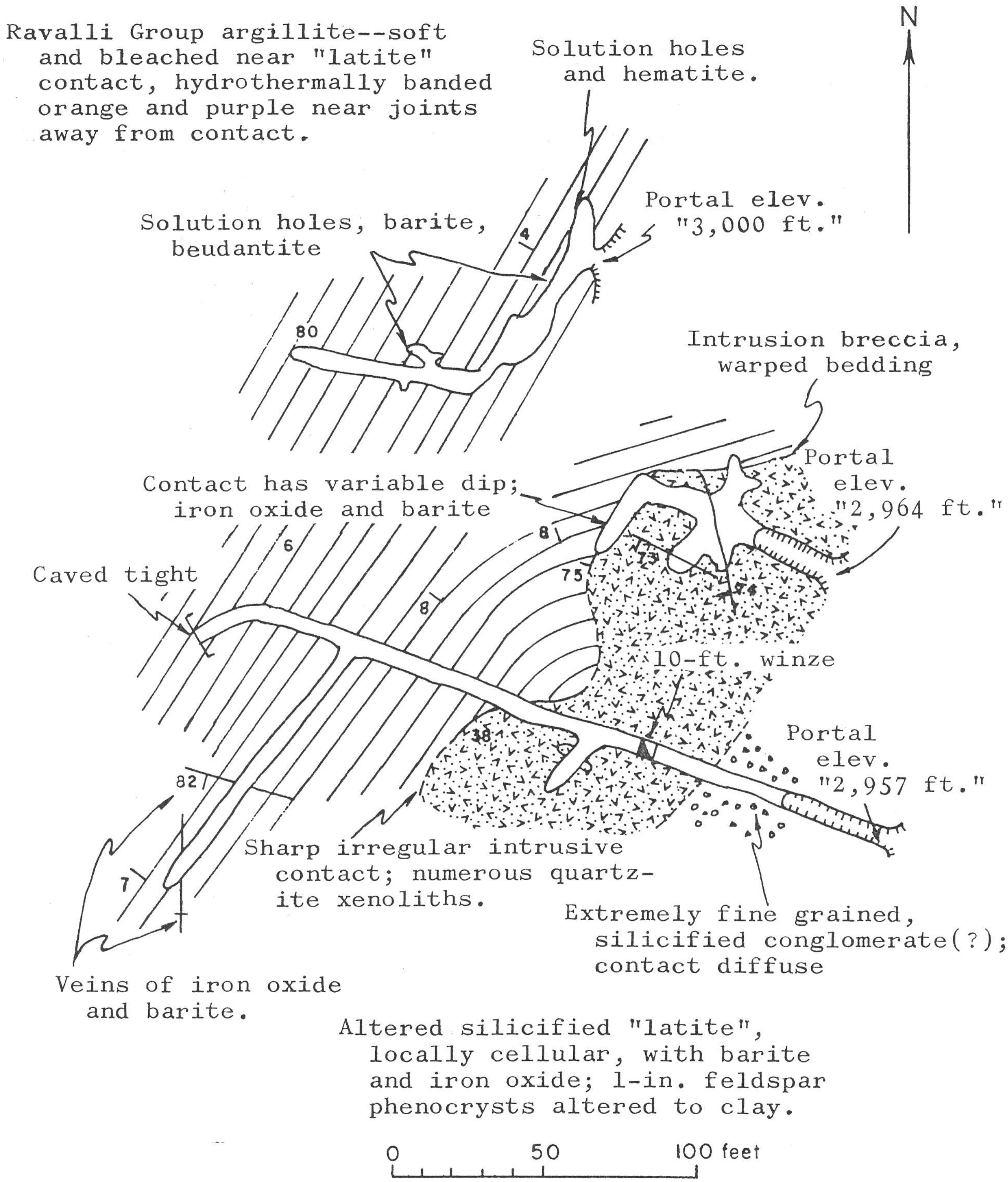

Figure 5.--Geologic map of Ole mine.

the igneous body and has been bleached along joints and bedding surfaces for several hundred feet from the intrusion. The uppermost workings in the argillite have exposed small, irregular solution holes that have hard, intensely silicified walls, and were probably formed by fumarole activity. Some of the holes contain beudantite, barite, and iron oxide. Even though these indications of mineralization are present, no large ore bodies have been found.

Birdseye and Maryann Mines

The workings of the Birdseye (fig. 6) and Maryann mines are in porphyritic latite and have mineralization very much like that of the Flathead mine, mainly argentite-galena in silicified cellular latite. Ore bodies discovered thus far are small.

Martin and Battle Butte Mines

The Martin mine (including the Battle Butte mine) (fig. 7) and related prospects were started in the late 1930's and have operated intermittently to the present. Most of the exploratory workings are inaccessible because of flooding and cave-ins. The mineralization is mainly base metal--zinc, copper, and lead--but includes some silver; the only zinc produced in the district came from the Martin mine. According to Waino Lindbom, ex-foreman of the mine, several sulfide ore bodies were discovered in the Martin shaft and the Battle Butte mine, but by the time a mill was constructed, a drop in base metal prices forced the mine to close.

Most of the workings are in altered andesite, which is probably intrusive. According to Lindbom, the Martin shaft extends at least 300 feet completely in andesite, whereas the Battle Butte shaft, 300 feet to the southeast, extends more than 100 feet completely in argillite. Moreover, surface excavation west of the shafts has exposed an intrusive relationship. Mineralization, similar to that in the Flathead mine, consists of sulfides in a silicified breccia zone in argillite of the Ravalli Group, chiefly as pods and veins in the breccia. Sulfides locally replace the breccia almost completely (Lindbom, personal communication).

Other Deposits

Although shallow prospects are numerous in the district, particularly in the vicinity of the Flathead and Martin mines, two unexplored mineralized areas found in the volcanic rocks probably warrant further exploration. In an area near the center of sec. 22, T. 25 N., R. 24 W., nodules of silica and iron oxides containing beudantite are scattered on the surface. The nodules probably result from fumarole activity possibly related to the quartz latite intrusive located a mile to the north. The

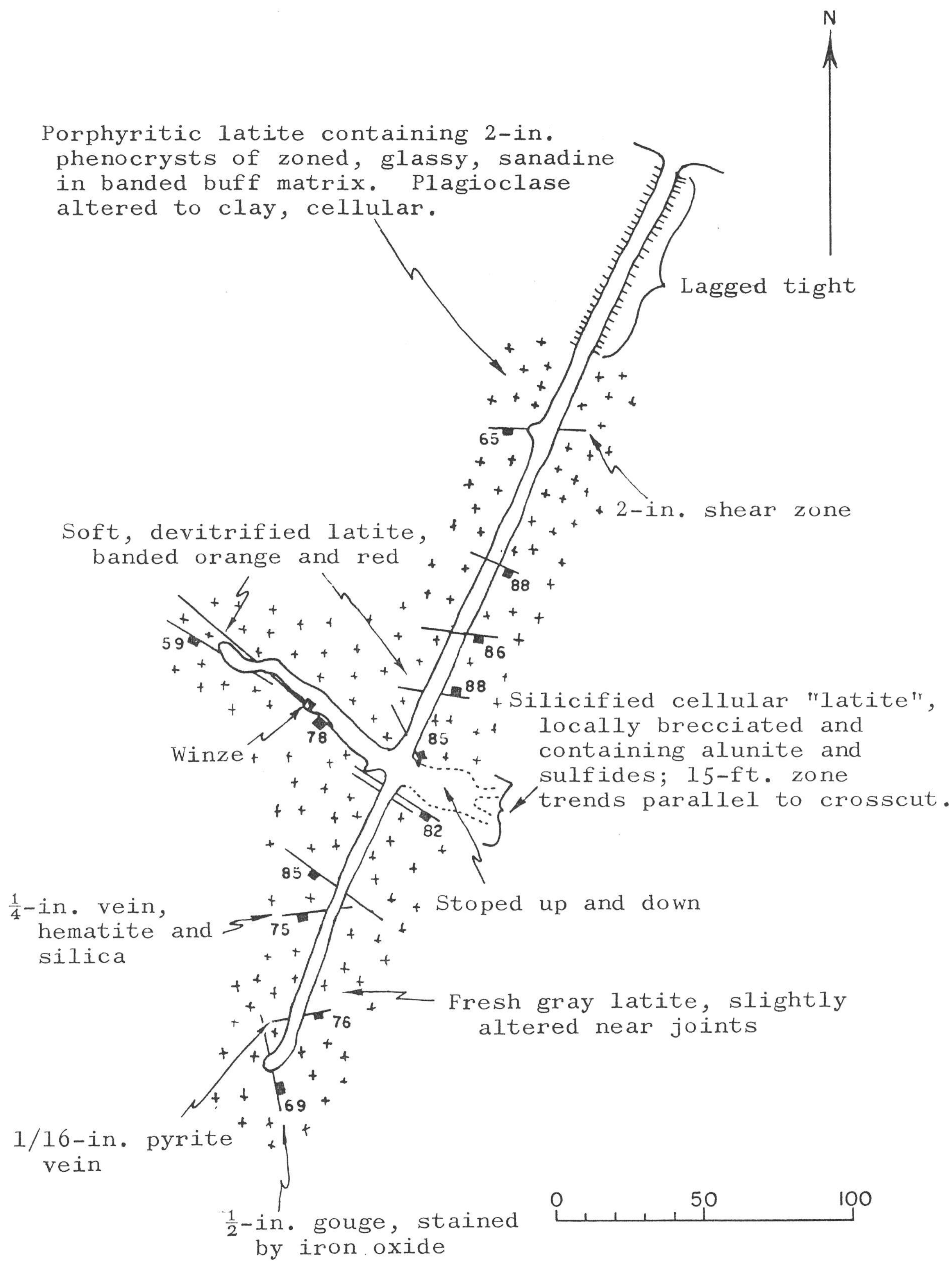

Figure 6.--Geologic map of Birdseye mine (main drift).

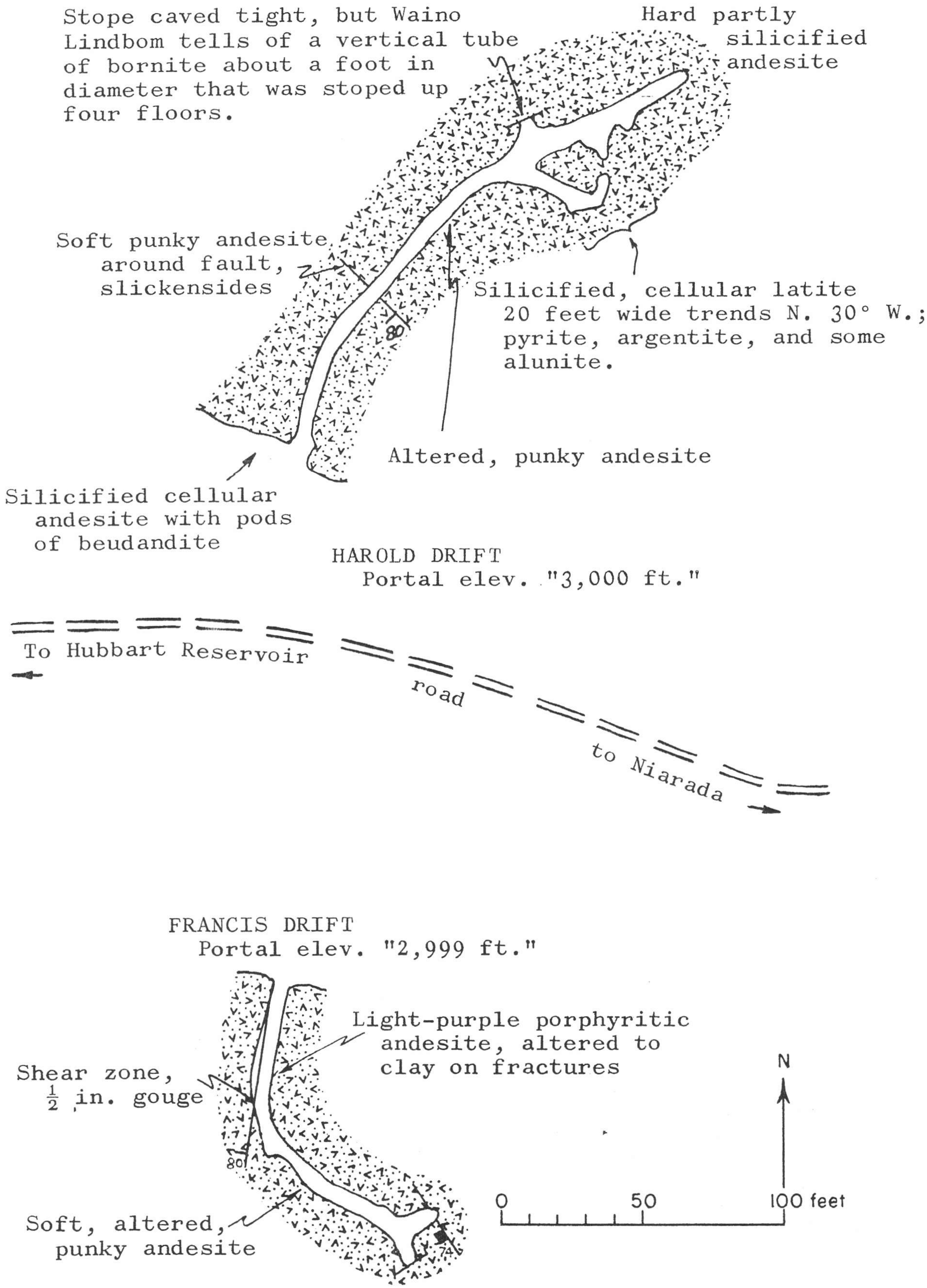

Figure 7.--Geologic map of west drifts, Martin mine.

nodules assayed only 0.3 ounce of silver per ton, but silver assays of surficial rock in the district are generally low.

In another area, just west of Hubbart Reservoir in the SE$\frac{1}{4}$ sec. 6, T. 25 N., R. 24 W., mineralization consists of limonite veins and nodules exposed in a recent dozer cut. Silver content assayed only 0.4 ounce per ton.

It has been reported that Paul Sperry discovered barite float near the center of sec. 29, T. 25 N., R. 25 W., north of the Flathead Indian Reservation boundary. Barite in place has not been found to date to determine the extent of mineralization.

DESCRIPTION OF MINING PROPERTIES, WHITEFISH, KALISPELL, SOMERS, COLUMBIA FALLS, AND STRYKER QUADRANGLES

Wort Prospect

The Wort prospect is in the SE$\frac{1}{4}$ sec. 11, T. 31 N., R. 23 W., on a ranch acquired by George S. Wort in 1948. The property is 7 miles northwest of Whitefish and about 150 feet south of the Great Northern mainline. The prospect is inactive, and the development work is believed to have been done during the early 1930's.

A 3-inch and a 4- to 6-inch vein striking east and dipping 70° S. contain white massive quartz, limonite, and siderite. The veins are developed by an 8 x 10 shaft 145 feet deep now filled with water. It is rumored that water became a problem at that depth. The workings are in lower Piegan (P_1) argillite striking N. 25° W., and dipping 36° E.

According to Vance Willeford of Whitefish, at a depth of 85 feet a drift from the shaft exposed a 30-inch vein assaying 4 percent copper and traces of lead and gold. The dump material examined contained no sulfides. The status of the property is unknown.

Micho Prospect

The Micho prospect is at the south end of the Whitefish Mountains on a southwest-flowing tributary of Haskill Creek in the S$\frac{1}{2}$ sec. 32, T. 32 N., R. 21 W. The workings include one adit, now caved, and two pits developed by the Micho brothers of Whitefish about 30 years ago. The caved adit trends N. 5° W. The workings are in contorted grayish-red sericitic argillite interbedded with layers of copper-stained white quartzite and sandstone. The sedimentary rocks are in the upper part of the Ravalli Group (Grinnell).

No minerals were noted on the dump, and it is thought that the excavations explored iron- and copper-stained beds of the Grinnell Formation.

Seek Prospect

The Seek prospect is on the west flank of the Swan Range a mile northeast of Lake Blaine in the NW$\frac{1}{4}$ sec. 24, T. 29 N., R. 20 W.

The development begun by Mr. Seek in 1922 includes a 12-foot cut and an 8-foot slightly inclined adit on a $2\frac{1}{2}$-foot white iron-stained quartzite bed in grayish-red argillitic siltstone of the Ravalli Group. The quartzite was not sampled.

Other Prospects

A 6-inch near-vertical quartz fissure vein containing iron oxides strikes N. 80° W. along the Truman Creek road in the NE$\frac{1}{4}$ sec. 10, T. 25 N., R. 22 W. It occupies a pre-existing fault in light-gray Ravalli quartzite and argillite. Ravalli rocks in the area strike N. 40° W. and dip 32° E.

An adit 150 feet long, bearing S. 74° W. in the NE$\frac{1}{4}$ sec. 12, T. 27 N., R. $21\frac{1}{2}$ W., was driven in middle Piegan (P_2) magnesian limestone striking N. 60° W. and dipping 11° S. The adit is believed to be in barren country rock, as no vein material was observed on the dump or in the workings. Oscar Oftedahl, who resides south of Foy Lakes, stated that test pits for placer gold were excavated on ridges between Patrick Creek and the drainage flowing north to Foy Lakes.

A rancher residing 10 miles northwest of Kalispell in the W$\frac{1}{2}$ sec. 12, T. 29 N., R. 23 W. is reported to have drilled a water well for stock to a depth of 56 feet, penetrating 28 feet of gravel and 28 feet of bedrock. Some of the excavated bedrock contained copper- and lead-bearing quartz. The water was green and unfit for stock, consequently the well was filled in.

On the slopes of Diamond Peak, about a mile northeast of Upper Whitefish Lake, small prospect pits were opened along a barren quartz vein. The vein strikes N. 80° E. and dips 68° S., parallel to the regional joint system in the region. The "vein" consists of a braided system of thin quartz seams having a total thickness of about 18 inches. The sheared zone was not sampled.

NONMETALLIC DEPOSITS

Nonmetallic deposits in the quadrangles are small but varied. Building stone has been quarried from the Horse Plains area. A small clay deposit near Woodland Park, southeast of the Great

Northern Railway trestle adjacent to the Kalispell city limits has produced clay used locally as a ceramic clay. Gravel and sand are moderately abundant within the major valleys. Lignitic coal occurs at the "Coal Banks" along Coal Creek, a tributary to the North Fork Flathead River. Marl deposits border and probably underlie Marl Lake in the western part of the Stryker quadrangle. Small amounts of peat are associated with marsh areas west of Whitefish and south of Creston.

Building Stone

The hydrothermally banded tuff in the north part of the Horse Plains quadrangle is quarried by the Montana Sunset Company for decorative building stone, but production is sporadic and total production is small.

Three quarries in the southeast corner of the Horse Plains area have produced lightweight concrete aggregate. The rock is a lightweight, porous, altered tuff, but because 10 to 20 percent of the rock consists of fragments of unaltered argillite and quartzite and because a large percentage is clay, the tuff is poor material for this purpose.

Limestone

Post-Belt limestone beds, except for the marl at Marl Lake, are absent throughout the map areas. A grab sample of marl at Marl Lake (sample no. S-32 in Appendix) contains 52.8 percent calcium oxide. The marl or fresh-water limestone at this locality is composed of fragments of late Cenozoic fossil shells.

Clay

Analyses of both Cenozoic lakebed clay and hydrothermally altered clay are listed in the Appendix of this report. The two major components of sampled clay are silica and alumina; calcium oxide and iron are present in minor amounts. The clay represented by sample number FC-2, from the north boundary of Woodland Park at Kalispell, has been used locally in small amount for ceramic clay. A clay deposit near Round Prairie on the North Fork Flathead River (sample number FC-6) is believed to be older than lakebed clays of Lake Missoula origin.

Some clay deposits in the Horse Plains area are possibly economic. They are mixtures consisting mostly of montmorillonite, but the deposits are hydrothermal in origin, therefore small.

Gravel and Sand

Heterogeneous mixtures of gravel and a small amount of sand are associated with morainal material and steam alluvium. In most surface exposures the deposits are unindurated, but deeper beds, exposed along the Flathead and North Fork Flathead Rivers, are cemented with a calcareous binder.

The Valley Sand and Gravel Company operates a gravel pit from a moraine and obtains gravel and sand by dragline from Flathead River bars. The operation is adjacent to U.S. Highway 2 bridge on the Flathead River in the NW$\frac{1}{4}$ sec. 2, T. 28 N., R. 21 W. The Flathead County Road Department operates a gravel pit in the SE$\frac{1}{4}$ sec. 3, T. 28 N., R. 21 W., on stratified and fairly well sorted material possibly in part related to a deltaic deposit formed when the alluvium-bearing river emptied into the glacial lake occupying Flathead Valley while at a temporary level slightly above 3,000 feet.

A morainal gravel deposit is being excavated by the Mount View Paving Company adjacent to the Stillwater River in the NW$\frac{1}{4}$ sec. 8, T. 28 N., R. 21 W.; the Engebretson Gravel operation is excavating the eastern extension of this morainal deposit in sec. 8.

Other gravel pits throughout Flathead and Stillwater Valleys have intermittently provided gravel and sand for road construction and other uses.

Coal and Peat

Coal lands belonging to the First National Bank of Butte are situated on the "Coal Banks" along Coal Creek adjacent to the North Fork Flathead River in northern Flathead County. The ground is in parts of sec. 18, 19, 20, 28, 29, 30, 32, and 33, T. 34 N., R. 20 W., on a gentle east-dipping bench covered with second-growth lodgepole pine.

The North Fork mine, in lot 8 of sec. 33, was operated on thin beds of lignite in the lower part of the Kishenehn Formation striking N. 55° to 60° W. and dipping 30° to 40° N. (Erdmann, 1947, p. 207-210). The mine is reached by a short access road from the North Fork road at a point 6.3 miles above Big Creek Ranger Station. The present installations include a tipple and six buildings, of which only two are in fair condition.

The North Fork mine was visited by C.E. Erdmann in 1934, at which time the daily production amounted to 10 tons, and total production for 1933 amounted to 600 tons. Small-scale mining operations had been carried on for several years at the property. According to Ted Ross of Polebridge, the property was active between 1936 and 1942, and coal was sold at $6 a ton throughout

Flathead Valley. The mine was closed at the beginning of World War II and has been idle subsequently.

The mine was developed by a southwestward-bearing adit (now caved) adjacent to and about 13 feet above the North Fork Flathead River. Considerable water was encountered in the adit during mining operations. Black lignite interbedded with thin seams of clay and sandstone occurs in a bed described by Erdmann (1944, p. 111) as 25 feet thick, only the upper 6 to 8 feet of the bed was mined to exploit a lignite seam 3 feet thick.

Tom Crum reports the occurrence of a lignite outcrop on lower Hay Creek road, 10 miles northwest of the "Coal Banks", and Erdmann (1947, p. 157) describes a 500-foot adit striking northwestward and located on the right bank of the Flathead River in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 19, T. 31 N., R. 19 W. The adit was driven in red-gray clay containing carbonaceous streaks and fragments of carbonized logs. Erdmann stated that the carbonaceous material is probably of early Pleistocene age but was mistaken for Tertiary coal-bearing strata such as crop out at the "Coal Banks" at Coal Creek.

A peat deposit borders and probably underlies a small lake in the SW corner of the SW$\frac{1}{4}$ sec. 35, T. 31 N., R. 22 W., about 1$\frac{1}{2}$ miles west of Whitefish. Peat in considerable amount occurs adjacent to a creek on the Walter C. Robbin ranch 3$\frac{1}{2}$ miles south of Creston in the SE$\frac{1}{4}$ sec. 34, T. 28 N., R. 20 W.

Oil and Natural Gas

Oil and natural gas seepages have been reported in the Bigfork-Creston area of Flathead Valley by a few ranchers who encountered rare gas seeps while drilling water wells. The seepages may be related to the Swan fault and the fault paralleling the east shore of Flathead Lake, which displace east-dipping strata of the Belt Series.

Rocks of younger age than the Belt Series could occur at depth beneath Flathead Valley, or the source might be Tertiary sediments buried beneath glacial drift within the valley proper.

In 1946 Herb Poston of Kalispell drilled a well to a depth of 1,475 feet to explore an area several miles southeast of Kalispell for potential oil and gas. Gravel was penetrated for the entire depth of the hole, and the well was abandoned.

A Flathead Valley rancher living in the vicinity of Creston is reported* to have drilled a well to 700 feet through gravel, sand, and clay before abandoning the drilling.

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*Personal communication, Oscar A. Moen.

GROUND WATER

Artesian water south of the area in Little Bitterroot Valley comes from Pleistocene or Tertiary sand, which underlies several hundred feet of glacial Lake Missoula silt and clay (Meinzer, 1916).

Although no wells are known to have been drilled in the map area, mapping north of Niarada suggests that there may be ground water in the Tertiary pre-volcanic drainage channels. Undoubtedly the flows, even though broken by faults, occupy ancient stream valleys and are underlain by Tertiary gravel. The outcrop pattern of the volcanic rocks is generally dendritic, indicating that they are valley fillings. Ground water will probably be found along any of the drainage ways, but particularly important might be the pre-volcanic valley of Little Bitterroot River. In sec. 21 and 22, T. 25 N., R. 24 W., the volcanic flows have been faulted, and are narrower in outcrop, possibly restricting ground-water movement. In addition, the source area is large; the flows in Tertiary time blocked Clear, Tamarack, Redmond, and Briggs Creeks, which now occupy broad alluvial valleys.

In addition to ground water in buried Tertiary alluvium, ground water will probably be found in pre-Wisconsin stream gravel, which must underlie the glacial lake deposits in Brown's Meadows. Even though the recharge area is small, the ground water would be sufficient to supplement irrigation in Brown's Meadows. Welcome Spring (sec. 35, T. 26 N., R. 23 W.) is a cold (42°F) spring flowing out of what seems to be a thin veneer of glacial drift; it may be related to an old Pleistocene stream.

SUGGESTIONS FOR PROSPECTING

As a result of the recent increases in the price of silver, prospecting in the area probably will become more active, and new ore deposits may be found. In the Hog Heaven area, supergene enrichment of silver ore should be found near the surface, but base-metal deposits may extend to depth. The ore deposits are likely to be small, high-grade, irregular bodies that are controlled by fissures or "fumarole holes". Ore may be found in the north Horse Plains quadrangle in either the volcanic rocks or the sedimentary rocks of the Ravalli Group near intrusive bodies where surficial oxidation products such as alunite, beudantite, and barite will indicate mineralization.

Detailed geologic mapping of the volcanic flows and intrusive bodies and differentiation into different rock types, in addition to a detailed division of the Ravalli Group into formations, would delineate structure and areas of possible mineralization. Geochemical prospecting used in conjunction with the mapping would be a good tool for locating areas of mineralization. Some work along these lines has been done, and both the Sunshine Mining Company and the Northern Pacific Railway Company have found geochemical anomalies.

Two significant trends of mineralization zones were noted in the Horse Plains area (pl. 4). Both zones trend east-west and are marked by prospects and mine locations. The northern trend extends from the Ole mine to the Birdseye mine; a mile to the south, the other trend extends through the Martin mine. Considering that all the production in the district has come from these two trends, and considering that intrusive bodies occur in both, prospecting in these zones and along their extensions may prove fruitful.

APPENDIX.--Analyses of clay and marl in Flathead and Lincoln Counties, Montana.

Sample no.	Location	CaO %	MgO %	Al_2O_3 %	FeO %	Fe_2O_3 %	K_2O %	Fe %	SiO_2 %	F %
FC-1	Lacustrine clay, NW$\frac{1}{4}$ sec. 8, T. 28 N., R. 21 W.	10.40		14.32				2.80	54.60	
FC-2	Lacustrine clay, SW$\frac{1}{4}$ sec. 8, T. 28 N., R. 21 W.	8.90		14.34				2.60	54.40	
FC-3	Lacustrine clay, SE$\frac{1}{4}$ sec. 5, T. 28 N., R. 21 W.	9.00		14.32				2.40	55.96	
FC-4	Lacustrine clay, SW$\frac{1}{4}$ sec. 5, T. 28 N., R. 21 W.	9.20		12.96				2.00	58.64	
FC-5	Lacustrine clay, NE$\frac{1}{4}$ sec. 3, T. 27 N., R. 20 W.	1.20		15.84				2.80	67.40	
FC-6	Tertiary(?) clay, SE$\frac{1}{4}$ sec. 30, T. 36 N., R. 21 W.	nil		16.98				2.10	68.76	
FC-7	Lacustrine clay, sec. 21 & 22, T. 35 N., R. 21 W.	1.20		15.70				2.60	67.84	
W-6	Lacustrine clay, SW$\frac{1}{4}$ sec. 18, T. 31 N., R. 22 W.	1.50		16.04					68.00	3.00
K-5	Lacustrine silty clay, sec. 12, T. 26 N., R. 21 W.	5.20		9.88					71.80	1.90
4-1-1	Lacustrine clay, sec. 18, T. 26 N., R. 19 W.	4.00	3.80	20.90	4.00	5.70	2.90		51.80	
4-1-2	Lacustrine clay, sec. 18, T. 26 N., R. 19 W.	1.00	3.60	23.60	3.80	5.40	3.60		54.00	
S-32	Grab sample marl, sec. 3 & 4, T. 34 N., R. 26 W.	52.80	0.08			0.20			0.70	
P-61	Kaolinitic clay, SW$\frac{1}{4}$ sec. 26, T. 25 N., R. 24 W.	0.29		19.04					65.78	0.35
P-136	Clay, NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 22, T. 25 N., R. 24 W.	3.40		16.16					67.80	1.70
P-139	Hydrothermal clay, sec. 18, T. 25 N., R. 24 W.	0.90		17.18					73.84	1.60

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