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U. M. Sahinen, Director

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Geology and Mineral Deposits of Lincoln and Flathead Counties, Montana

by

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Montana Bureau of Mines and Geology

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FOREWORD

This publication represents an outstanding example of cooperation between industry and a state agency in an attempt to assist and promote mineral development in Montana. The Great Northern Railway Company (now Burlington Northern Inc.), the Pacific Power & Light Company, and the Montana Bureau of Mines and Geology combined their talents and resources in this effort to improve the economy of northwestern Montana by surveying the potential for mineral development in Lincoln and Flathead Counties. The intended result would be a broader tax base for the state and the counties, increased power sales by PP&L, and increased transportation sales by Burlington Northern.

The emphasis of the report is on metalliferous mineral occurrences and the related geology. The area is a promising mineral province; the geologic structures and host rocks are favorable for the accumulation of ore deposits. Geochemical studies indicated several anomalous areas that are recommended for detailed exploration, as reported in Montana Bureau of Mines and Geology Bulletins 48 and 61.

This area seems to have some geologic resemblance to the Coeur d'Alene mining district a short distance to the west in Idaho. Similarities in host rocks, structures, and mineralization have long been known, and recent studies indicate similarity in the geologic age of the ore deposits.

Lincoln and Flathead Counties have produced about $11.5 million from metalliferous mineral deposits, but the region is not thoroughly explored or developed and has a much greater potential for future production. In fact, partly as a result of this program, a major mining company has announced plans to develop a copper deposit, which promises to be a significant producer.

It is hoped that this survey will encourage additional mineral exploration, and that the resulting discoveries and production will enhance the development and economy of the region as a whole.

Uuno M. Sahinen, Director

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ABSTRACT

Lincoln and Flathead Counties occupy an area of 8,500 square miles in the northwest corner of Montana in the northern Rocky Mountain physiographic province, which fronts the Great Plains east of the Continental Divide. The area is characterized by high, rugged forested northwest-trending mountain ranges separated by narrow valleys. Tributaries of the upper Columbia River drainage system occupy these linear valleys.

The late Wisconsin Cordilleran ice advancing south from British Columbia covered the land surfaces of northwest Montana to altitudes of 6,000 feet or more. Thickness of the ice ranged from about 4,000 feet at the International Boundary to at least 2,000 feet near Kalispell, then decreased rapidly to the margin near Polson. Alpine glaciers from the high mountain ranges merged with the Cordilleran ice. The southern limit of the ice conforms approximately to the south boundary of the map in the Flathead Lake-Thompson River area, then swings diagonally northwest to the Idaho border; the Cabinet Mountains acted as a barrier to the advancing ice. Glacial stratified and nonstratified surficial deposits including drumlins and kame terraces, till, and outwash floor the valleys. Glacial Lake Missoula, covering an area of about 3,3000 square miles, was created by glacial melt water; the northern arms of the lake probably extended up the Vermilion, Thompson, and Little Bitterroot Rivers, and Mission Valley.

In the map area, the Belt (late Precambrian) consists of fine-grained clastic and carbonate rocks 17,000 to 40,000 feet thick, which have undergone regional low-grade metamorphism (greenschist facies). Belt rocks crop out in northwest-trending patterns and underlie the whole area, but are overlain by Paleozoic and Mesozoic sedimentary rocks in the northwestern and southeastern parts of Flathead County.

Major facies changes complicate the study of Belt stratigraphy. The Prichard Formation of the Pre-Ravalli Group is the lowest Belt unit exposed; a calcareous zone near the top of the formation seems to thicken eastward from central Lincoln County. From west-central Lincoln County, the overlying Ravalli Group thins northward, and from the west to the east side of the Rocky Mountain Trench, Ravalli strata exhibit a fairly abrupt color change from gray to grayish red purple (Grinnell Formation). Several hundred feet of upper Ravalli strata southeast of Vermilion River are assigned to the St. Regis Formation, but equivalent strata were not recognized to the northwest. From western Lincoln County eastward, the next younger group, the Piegan Group (Wallace Formation) thins and becomes increasingly calcareous, to the extent that the Middle Piegan (Siyeh Formation) in the Salish Range is mapped as an impure limestone. The lower part of the Striped Peak member of the Missoula Group, which overlies the Piegan or Wallace, is quartzite in the Thompson Lakes-Fisher River area, but is argillite and shaly argillite farther north.

Paleozoic sandstone, shale, limestone, and dolomite total 4,500 to 5,300 feet in thickness. Mesozoic fissile shale and fossiliferous carbonate rock 500 to 1,500 feet thick occupy small areas. A Tertiary lignitic siltstone, sandstone, claystone, and conglomerate sequence 3,000 feet thick is exposed in the valley of the Flathead River (North Fork). Late Cenozoic deposits fill the Flathead Valley and other major valleys to depths locally exceeding 1,400 feet.

Dikes, sills, and stocks ranging in composition from granitic to ultrabasic rocks intrude Belt strata in the map area; these igneous rocks are most abundant in western Lincoln County and are scarce elsewhere. Tertiary volcanic rocks of latite, andesite, and sparse basalt overlie the Ravalli Group in southwestern Flathead County (Hog Heaven district).

Major faults strike between north and northwest and are parallel or subparallel to folds. Major west-dipping or vertical reverse and normal faults include the Leonia, Pinkham, Mission, Swan-Whitefish, and Flathead-Tuchuck Faults. Subsidiary east- and northeast-striking structures displace earlier northwest faults. The master fault of the region, the Lewis Thrust, parallels the eastern front of the Rocky Mountains from Roosevelt Pass southeastward. Tight to broad symmetrical, asymmetrical, and overturned folds plunge north or south; some are double plunging. Traces of some axial planes have been mapped for distances of 40 miles, but most folds are much shorter.

Mineral deposits have yielded silver, lead, gold, zinc, copper, and tungsten in eight mining districts within the area mapped. Significant amounts of placer gold have been produced from Lincoln County. The major precious and base metal production has come from the Flathead mine, in Flathead County, and the Snowstorm and Snowshoe mines, in Lincoln County, Vremiculite, mined from the Rainy Creek pluton in Lincoln County, has been the major mines, in Lincoln County. Vermiculite, mined from the Rainy Creek pluton in Lincoln County, has been the major nonmetallic mineral produced from the area; barite, talc, clay, tremolite, sand and gravel, and stone deposits are mentioned, and of these, production of stone may very well become significant.

Although the total base and precious metal production from Lincoln and Flathead Counties is valued at only $11.5 million, the region shows a greater potential future production. A major mining company is developing a promising copper deposit in the western part of the area, and geochemical work done by the Bureau as part of this project but described in separate reports (Bull. 48 and 61), indicates other areas in which further exploration may yield additional discoveries.

INTRODUCTION

With the common interest and purpose of furthering the economic development and stimulating growth of population and business in their service area in northwestern Montana, the Pacific Power & Light Company and the Great Northern Railway Company entered into an agreement with the Montana Bureau of Mines and Geology "To cooperate in a project of exploration and geological survey and mapping work designed to discover and make available to the parties and to the general public as much additional geological information as possible concerning the area, in the form of maps, reports, and studies." The project known as the Kootenai-Flathead project was started in June 1958. Although originally intended as a five-year project, mapping was continued for six years. Two additional years were spent in geochemical investigations, the results of which appear in other reports of the Bureau (Bull. 48 and 61).

A field office was established at Kalispell for the duration of the project, to provide mineral- and rock-identification service to prospectors of the area, and to advise them on mineral exploration and development.

Six progress reports on geologic mapping and mines and two on geochemical sampling (Bull. 48 and 61) have been issued. This report will be the final summary report on mapping and will supersede Bulletins 12, 17, 23, 29, 36, and 42.

Geologic data were plotted on U. S. Forest Service planimetric base maps (2 inches to 1 mile) and on aerial photographs (1:20,000). Enlarge ments of U. S. Geological Survey 30-minute topographic sheets of the Thompson Lakes, Stryker, Kintla Lakes, and Silvertip quadrangles were also used. In this report, however, the quadrangle names are not used, as the U. S. Geological Survey, Topographic Branch, is remapping the area on 7½-minute quadrangle maps, some of which have the same names as the now obsolete 30-minute sheets.

The Kootenai-Flathead project area is bounded on the west by the Idaho border at longitude 116°2'52.99" west (Van Zandt, 1966, p. 236) and on the north by the International Boundary at latitude 49° north. The east boundary corresponds to the west and south boundary of Glacier National Park from the 49th parallel southeastward down North Fork and up Middle Fork Flathead Rivers to Bear Creek and northeastward up Bear Creek to Marias Pass; from Marias Pass southeastward to the north line of Powell County the project area is bounded on the east by the Continental Divide. From the Continental Divide, the south boundary extends west along the north boundary of Powell and Missoula Counties to the eastern boundary of Lake County, thence northward along the Lake County boundary to latitude 47°52'30", thence west along this parallel as far as the 115th meridian, thence north up the meridian to the 48th parallel, thence west to the boundary between Lincoln and Sanders Counties, thence generally westward along the county line to the Idaho border (Fig. 1). The project area includes all of Lincoln and Flathead Counties, the north part of Lake County, and two small tracts in the northeast part of Sanders County. The mapped area totals about 9,200 square miles, of which 160 square miles is water.

The project area is crossed by U. S. Highway 2 from the Idaho boundary eastward through Troy, Libby, Kalispell, and West Glacier to Marias Pass, and by U. S. Highway 93 from Dayton northwestward through Kalispell and Eureka to Roosville. State Highway 37 extends northeast from Libby along the Kootenai Valley to U. S. Highway 93 just north of Eureka. State Highway 35 follows the east shore of Flathead Lake north from Polson and joins U. S. Highway 2 just east of Kalispell. Other access is provided by county and forest service roads, logging spur roads, mine access roads, and in more remote areas by forest service trails. Four-wheel-drive vehicles are needed to reach a few areas, but most roads are passable by passenger car.

The main line of the Great Northern Railway follows the Kootenai Valley from Leonia via Troy and Libby to Rexford, the Tobacco River and Flathead valleys through Eureka, Whitefish, and Columbia Falls, and the Glacier Park boundary from West Glacier through Marias Pass. Plans for construction of the Libby Dam on the Kootenai south of Warland necessitated rerouting of the main line via Wolf Creek and Fortine Creek to Whitefish.

PREVIOUS WORK

Many reports have been published on geography, geology, and mining activities throughout northwest Montana. Gibbs (1873), one of the first investigators, described the physical geography along the Canadian boundary. Some early references to mines and prospects in eastern Flathead County were included in forest reserve studies by Ayres (1899, 1901) and Chapman (1900). Willis (1902) made the first comprehen-

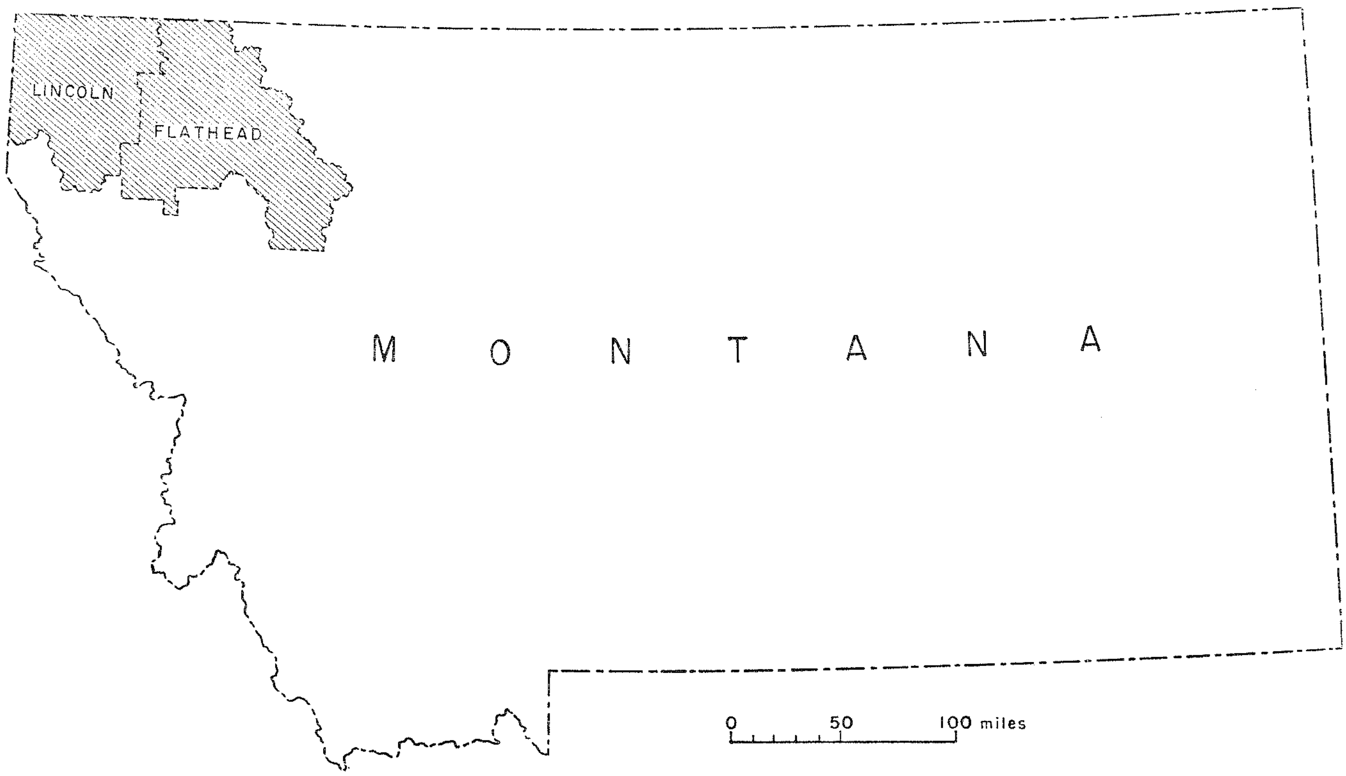

Figure 1.—Index map showing location of Lincoln and Flathead Counties.

sive study of Belt rocks (Precambrian) in the Lewis and Livingstone Ranges of Glacier National Park. Walcott (1906) described measured Belt sections in the Mission and Swan Ranges and published the first correlations of Belt rocks in northwestern Montana and northern Idaho.

G. S. Lambert, A. C. Bevan, R. A. Wilson, E. B. Young, and C. H. Clapp mapped the Salish Mountains and adjacent areas in western Flathead County between 1921 and 1924; their results were published in part (Wilson and others, 1924; Bevan, 1929). Their work was later incorporated in the Geologic Map of Montana (Ross and others, 1955). Over a period of years C. H. Clapp (1932) mapped a considerable area extending northwestward from the Missoula-Drummond-Helena area to the southern Whitefish Range. A detailed stratigraphic study (C. L. and M. A. Fenton, 1937) was concerned with subdivision of the Belt Series in Glacier National Park. C. P. Ross (1949, 1959, 1963), in regional studies throughout Montana, contributed in large measure to the present knowledge of Belt Series stratigraphy and structure and was co-author of the report of an investigation (Ross and Rezak, 1959) of rocks and fossils in Glacier National Park. Rezak (1957) classified the Precambrian stromatolites of Glacier National Park.

C. F. Deiss (1933, 1935, 1938, 1941, 1943a, 1943b) mapped the Silvertip quadrangle (including southeastern Flathead County) and parts of the adjacent Saypo, Ovando, and Coopers Lake quadrangles, and studied the stratigraphy of Precambrian and Paleozoic rocks in these areas. Sloss and Laird (1945, 1947) prepared reports on Devonian and Mississippian stratigraphy in northwest Montana in connection with oil and gas investigations. Mudge and others (1962) subdivided Mississippian strata in the Sawtooth Range. Studies in the Sawtooth Range by Mudge (1965, 1966a, b, c) and in the southern part of the Lewis and Clark Range by McGill and Sommers (1967) have been published.

The Rocky Mountain Trench of southern British Columbia and northwest Montana has been the subject of papers by Flint (1924), Shepard (1922, 1926), and Leech (1959). Other contributors to the geology of the region are Pardee (1950), who postulated block faulting in intermontane valleys, Childers (1963), who mapped an area south of Glacier National Park, and Sweeney (1955) and Bentzin (1960), who reported on parts of the Whitefish Range.

Within western Lincoln County, Gibson (1948) and associates studied the geology and ore deposits of the Libby quadrangle. Publications by Gale (1934), Gibson (1934), and Gibson and Jenks (1938) are indirectly related to this study. Gibson and others (1938) presented studies of the igneous rocks in the Libby quadrangle.

Mines and mineral deposits were examined by MacDonald during a reconnaissance survey of the general economic geology of the Cabinet and Purcell Mountains (Calkins and MacDonald, 1909). Schrader (1911) also reported on early mining activity and placer operations in the Libby district and adjacent areas. Billingsley (1915) prepared an unpublished report on mineral deposits in parts of Lincoln County. Pardee and Larsen (1929) and Perry (1948) described the occurrence of vermiculite in the Rainy Creek pyroxenite stock in the Rainy Creek district northeast of Libby. Boettcher (1963) reported on the geology, petrography, and geochemistry of the Rainy Creek pluton. Geology and ore deposits of the Hog Heaven district, including the Flathead mine, are subjects of a paper by Shenon and Taylor (1936). Sandvig (1947) listed mines and placers in the Libby, Troy, West Fisher, and Hog Heaven districts, and Crowley (1963) published a report on mining properties in Sanders County, several of which are described in this report.

Geologic studies of Belt rocks outside of Montana but peripheral to Lincoln County were made by Daly (1912) along the 49th parallel and these were followed by some revision of Daly's mapping and stratigraphic nomenclature by Schofield (1914a, 1915). Leech (1958, 1960) mapped the Cranbrook-Fernie area in southeastern British Columbia. Kirkham and Ellis (1926) published a reconnaissance map of Boundary County, Idaho, and Harrison and Jobin (1963) discussed the stratigraphy and structure of the Clark Fork area of northern Idaho. Price (1962) mapped Precambrian, Paleozoic, Mesozoic, and Cenozoic rocks in southeast British Columbia and southwest Alberta.

Glaciation of parts of northwest Montana was studied by Davis (1916, 1921), who made observations relative to the steep west fronts of the Mission and Swan Ranges. Alden (1953) reported on glaciation in the Kootenai, Tobacco, Stillwater, and Flathead Valleys. Erdmann (1944, 1945, 1947) published detailed studies of possible damsites along Kootenai River west of Libby, and on structure, economic geology, and glaciation of the Hungry Horse damsite and reservoir area and other proposed damsites on the Flathead River and its tributaries.

ACKNOWLEDGMENTS

The Kootenai-Flathead mapping project owes its inception to a planning meeting held in Butte on March 5, 1958. Present were Al Haley and Ralph Watson of the Great Northern Railway Company, Lew Growney and Garth Duell of the Pacific Power & Light Company, and Edwin G. Koch, Walter S. March, Jr., and Uuno M. Sahinen of the Montana Bureau of Mines and Geology. An operations committee consisting of Watson, Duell, and Sahinen was appointed to supervise the project. Willis M. Johns was selected as project geologist. In later years the operations committee was assisted by alternates Henry E. Reed of the Great Northern Railway Company and Winston M. Sahinen of Pacific Power & Light Company.

Graduate assistants who aided in field mapping were D. H. Dahlem (Montana College of Mineral Science and Technology), L. P. Beer (University of Massachusetts), A. W. Shelden (Montana State University), D. A. Sommers (University of Rochester), F. V. Latuszynski (University of Montana), W. D. Page (University of Colorado), W. C. Barnes (Princeton University), A. G. Smith (Princeton University), F. W. Hall (University of Montana), and E. H. Gilmour (University of Montana).

Assistant geologists who contributed significantly to the field mapping were D. M. Hutchinson, K. T. Bondurant, A. L. Boettcher, and W. L. Newell.

Appreciation is expressed to Mr. U. M. Sahinen, Director of the Montana Bureau of Mines and Geology, for his many helpful suggestions and critical revision of the manuscript and for his assistance throughout the entire course of the project, to Dr. J. C. Maxwell of Princeton University for additional data on the Pinkham fault in the Rexford area, and to Dr. R. B. Berg of the Montana Bureau of Mines and Geology for checking and extending the thin-section study. Dr. W. C. Barnes graciously permitted the use of his report and map of the northeast Whitefish Range done under the direction of the Geology Department of Princeton University.

Mr. Don C. Lawson, mineral technician, Montana Bureau of Mines and Geology, assisted in preliminary soil-sampling work during the final phases of the program. Mineral and rock analyses were performed by Mr. F. P. Jones and the late Mr. C. J. Bartzen, Bureau analysts. Mr. R. B. Holmes, Bureau draftsman, assembled tables and drafted maps and illustrations for this report.

The writer thanks the many individuals who graciously contributed services and information on location, history, and production of mining properties throughout the area. These include Mr. A. M. Bartlett, Mr. Dan Garrison, Mr. Jack Garrison, Mr. Allen Goodgame, Mr. Jim Lyle, Mr. W. A. Rankin, Mr. Ernest Williams, Mr. L. W. Bolyard, Mr. Blaze Echo, Mr. Clive Roark, Mr. W. C. Zollars, Mr. G. G. Kenelty, Mr. C. Tallmadge, and the late Mrs. Elizabeth Powers, Mr. Leslie W. Leigh, Mr. Henry P. Reinshagen, Jr., and Mr. J. K. Potter, all of the Libby-Troy area; Mr. H. K. Waylett, Mr. O. V. Miller, Mr. D. Larue, Mr. J. D. Daniel, Mr. W. L. Fewkes, Mr. Oscar Moen, Mr. B. Hansen, and the late Mr. Albert Thayer of the Fisher River-Rexford-Eureka area; Mr. Marion Fishel, Mr. Guy Maycumber, Mr. Carl Luke, Mr. A. E. Lewis, Mr. U. L. Poston, Mr. H. L. Poston, Mr. W. C. Kirkpatrick, Mr. Vern Strodtbeck, Mr. A. Darling, Mr. A. M. Johnson, Mr. Glen Bauska, Mr. Frank Bauer, Mr. Ben Trosper, Mr. Barry Adkins, Mr. Al Harvey, Mr. H. E. Bear, Mr. R. L. Bear, Mr. O. G. Tiegan, Mr. Barton Pettit, Mr. Thain White, Mr. Waino Lindbom, Mr. Oscar Oftedahl, Mr. Levi Gaustad, Mr. John Jense, Mr. Paul Jense, Mr. Norman Stringfellow, Mr. Ray Hough, Mr. Bill Adams, and the late Mr. F. A. Stahl, Mr. Harold Luke, and Mr. Jim Whilt of the Kalispell-Dayton area; and Mr. Ted Ross, Mr. Tom Crum, Mr. Earl Scott, Mr. Ed Smith, Mr. Walter Bissell, and the late Mr. Vance Williford of the Whitefish-Olney-Polebridge area.

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GEOGRAPHY

GENERAL STATEMENT

Flathead County was created in 1893. A portion of the county was segregated in 1909 to form Lincoln County. Lake County was created August 10, 1923. Flathead County is the largest, 5,294 square miles, and has a population of 32,965 (1960 census). Lincoln and Lake Counties have populations of 12,357 and 13,104 respectively, and areas of 3,666 and 1,564 square miles. Federal ownership of land exceeds 73 percent in Lincoln and Flathead Counties, most of which is national forest. In Lake County 52.1 percent of the area is under federal control, part of the acreage being included in the Flathead Indian Reservation.

Lumbering, ranching, and farming are the essential industries in the area. Flathead Valley north of Flathead Lake contains rich farming land; cherries noted for size and flavor are grown on the shores of Flathead Lake and shipped to eastern seaboard cities. Many tourists visit the area, as Glacier National Park and Flathead Lake are among the leading vacation attractions in the state. Flathead County acquired a basic industry when The Anaconda Company erected an aluminum reduction plant near Columbia Falls.

Kalispell, a city of 10,000, is at the crossroads of U. S. Highways 2 and 93. Eureka (population 1,229), near the Canadian border, and Polson (2,314) at the south end of Flathead Lake, are along U. S. Highway 93. Other centers of population are Whitefish (2,965) and Columbia Falls (2,132) in Flathead County, and Libby (2,828) and Troy (855) in western Lincoln County.

Climatic conditions within the map area, as within the western mountainous part of the state, are affected by the Rocky Mountains, which act as a barrier to south-moving arctic and central Canadian storms, while restricting the eastward passage of moisture-bearing prevailing westerly winds from the Pacific Coast. The mountain barriers tend to make winters more moderate and summers cooler and to produce an increased amount of rain and snow; the Libby area lies within the snowbelt of western Montana and northern Idaho.

Average annual precipitation amounts to 16.5 inches in the eastern part and 18 inches in the western part of the map area. Annual mean temperatures range between 42.8°F and 44.5°F. At Kalispell, for the period 1956-61, the average maximum temperature was 54.2°F and the average minimum 31.3°F. Annual snowfall amounts to about 68 inches, although snowfall in the mountains may exceed 100 inches a year. The highest temperature recorded for Kalispell since 1920 was 104°F in 1960; the lowest was -38°F in 1950. The greatest amount of rain falls during May and June; July and August are relatively dry.

Thick stands of second-growth evergreens cover slopes and ridges, but both evergreens and deciduous trees grow in the valleys. Western yellow pine (ponderosa), western larch (tamarack), and Douglas fir make up the bulk of merchantable timber; white pine, lodgepole pine, white fir, cedar, and Engelmann spruce also are commercially important, but juniper and hemlock are not. Deciduous trees include cottonwood, quaking aspen, birch, alder, and willow. Common shrubs and flowers are huckleberry, serviceberry, beargrass, and Indian paintbrush. Native grasses, including timothy, white clover, quack grass, and fescue, thrive in valleys, high parks, and open south-facing slopes.

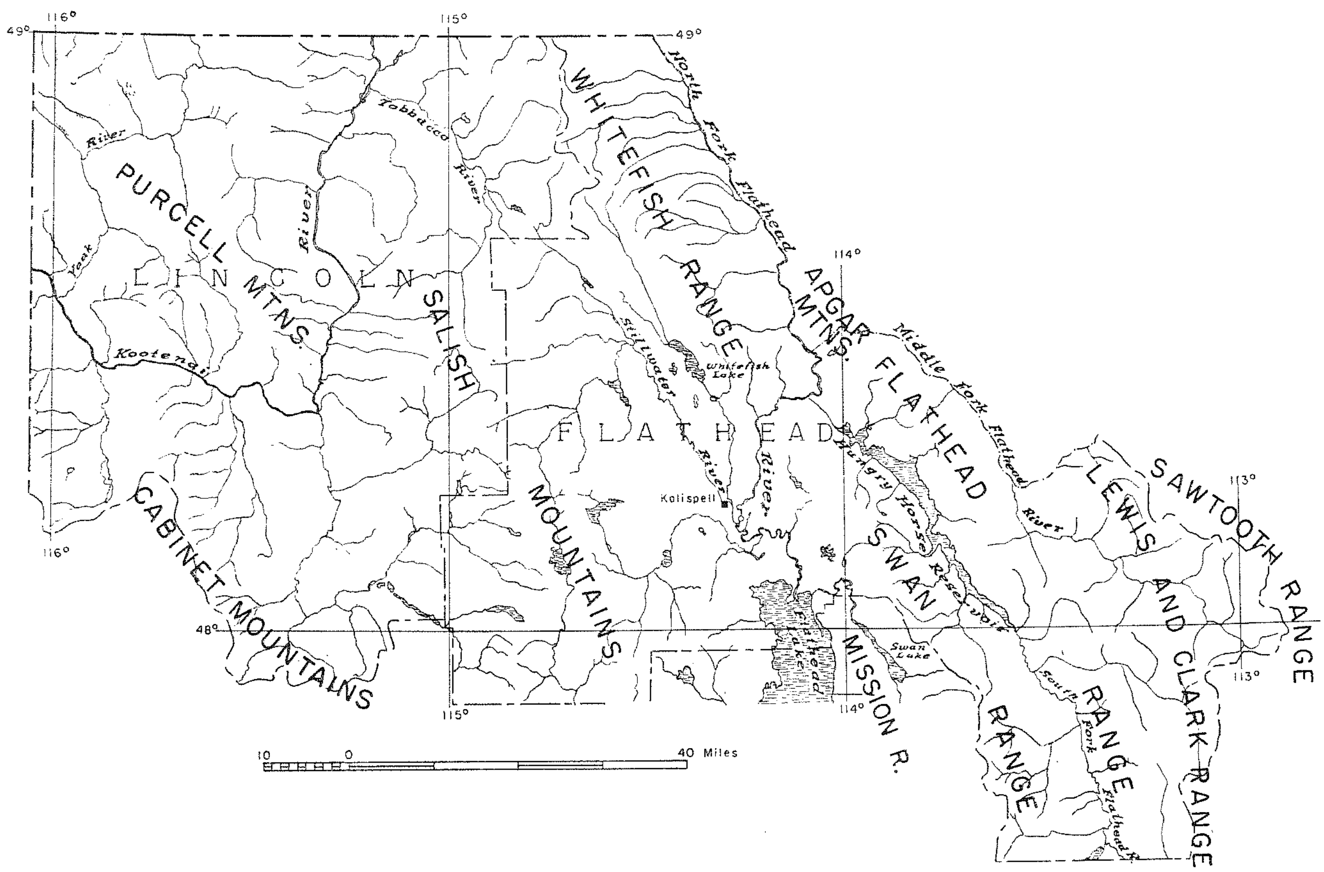


Figure 2.—Index map of northwest Montana showing mountain ranges.

PHYSIOGRAPHY

The area is in the Northern Rocky Mountain province (Fenneman, 1931), which here is characterized by successive heavily forested ranges trending north to northwest and separated by long straight valleys that show mature drainage patterns. Between the Idaho boundary and the Great Plains are a dozen linear ranges, eight of which are in the area described in this report. The intervening parallel or subparallel depressions are the valleys of the Kootenai, Thompson, and Flathead Rivers, and their nine tributaries, forming in Montana the upper Columbia River drainage system. The largest of the rivers are the Flathead and Kootenai, contributing average discharges near Polson and at Leonia, respectively, of 11,610 and 13,850 cubic feet per second.

Tectonic forces elevated the entire Rocky Mountain area in a broad upwarp and also caused the differential uplift of the individual mountain ranges by faulting. The Hope fault, which has a vertical component of 1,500 feet (Gibson, 1948, p. 65), borders the southwest flank of the Cabinet Mountains. The Swan fault, which has a stratigraphic displacement of 11,000 feet, borders the west flank of the Swan and Whitefish Ranges. A vertical component of several thousand feet for the Lewis thrust undoubtedly contributed to the elevation of the ranges that stand east of the Rocky Mountain Trench, especially in Glacier National Park and north of the International Boundary (Fig. 2).

Most of the ranges stand 5,000 to 7,000 feet above sea level, and the highest peaks reach altitudes of 7,500 to 9,000 feet. The highest point is Swan Peak, in the Swan Range, 9,255 feet. Other scenic peaks are Silvertip Mountain (8,890) in the Flathead Range, Pentagon Mountain (8,877) in the Lewis and Clark Range, Snowshoe Peak (8,712) in the Cabinet Mountains, Green Mountain (7,830) in the Whitefish Range, and Mt. Robinson (7,700) and Northwest Peak (7,518) in the Purcell Mountains.

In the western part of Lincoln County the valley of the Kootenai is locally 2 to 5 miles wide, as at Troy and at Libby, but throughout most of its length it is much narrower. Lowest point in the area is at Leonia (1,822 feet), where the Kootenai crosses the boundary into Idaho. The valleys farther east are wider; the Flathead Valley is as much as 16 miles wide within the study area, and the valley of Flathead River (North Fork) averages 8 miles in width. Throughout the area the smaller tributaries are perpendicular to the main streams, and they have cut narrow valleys or gorges down the mountain slopes.

Physiographic history of the Northern Rocky Mountains in Idaho and western Montana is complex. Workers are not in agreement on the course of events nor on the amount of reduction of land forms that took place during early and middle Cenezoic time (Fenneman, 1931; Atwood, 1916; Umpleby, 1912, 1913; Mansfield, 1923; Lindgren, 1904, 1918; and Blackwelder, 1912). Early workers disagreed about whether one or two "peneplains" developed and whether the valleys were filled with Tertiary sediments and then re-eroded in the same sites. Ross (1959) could find no evidence of peneplanation in the Flathead region, hence he believed that no plains topography extended westward into the area after the Lewis thrust and related tectonic activity (Laramide orogeny) elevated the area. This idea of a single post-Cretaceous uplift seems logical. The accordant summit levels that were presumed to indicate peneplanation are readily explained as the expectable result of erosion of similar rocks under similar climatic conditions throughout the area.

The foregoing comments are not meant to imply that tectonic activity ceased completely at the end of the Laramide orogeny. Subsequent folding and faulting may have been sufficient to produce some drainage changes, and may in fact be continuing at present, but only on a comparatively small scale. Numerous minor earthquakes have shaken the area, and these may indicate tectonic movement, although they may also indicate elastic rebound of the area after removal of the load of glacial ice that covered the region only a few thousand years ago.

GLACIATION

In the Kootenai-Flathead area, only the ice of the last stage of glaciation (Wisconsin) left positive evidence of its advance and retreat. Indications of earlier glacial action, if any, were removed by the ice during its last advance or were buried under the mass of material deposited by the ice and by its meltwaters. Alpine glaciers descending from the high ranges merged with and augmented the Cordilleran ice sheet, which advanced generally southeastward along the major valleys. Both the advance and the retreat were somewhat irregular, being interrupted by relatively brief reversals.

The Cordilleran ice sheet entered Montana from the north as individual lobes that filled the valleys, but at its maximum stage of development it probably covered most of the map area west of the Rocky Mountain Trench (Fig. 3). At the International Boundary the ice reached a maximum altitude of 7,300 feet (Daly, 1912). Northwest of Lakeside, near the north end of Flathead Lake, a moraine that dams a small lake indicates that the ice there reached a minimum altitude of 5,100 feet. Only a few miles farther south, the Lake Mary Ronan lobe scoured the Dayton bench at an altitude of about 4,200 feet, and the altitude of the top of the terminal moraine south of Polson averages about 3,400 feet. Greatest thickness of the ice ranged from about 4,000 feet at the International Boundary to at least 2,000 feet near Kalispell, then decreased more rapidly to the margin near Polson.

Striations and fluting of rock outcrops are the principal indicators of the direction of ice movement (Fig. 3). These markings are prominent on the more resistant quartzite of the Ravalli Group. Only a few scattered striae were observed on the softer beds of the Piegan Group. Distribution of drift and till, erratics, and moraines shows the extent of glaciation. Cirques and U-shaped and dissected hanging valleys characterize alpine glaciers, which originated on many of the high peaks and extended a short distance down the mountain valleys. At the same time, the Cordilleran sheet advancing along the major valleys sent prongs up the tributary valleys. Thus it is impractical to attempt to draw a "contact" between sheet and alpine glaciers.

The westernmost lobe of the Cordilleran ice in Montana followed up the West Fork of the Yaak and also down the main Yaak Valley but eventually overrode the divides to merge with adjacent lobes. On "The Scout" Mountain west of the headwaters of the West Fork of Yaak River, glacial striae at an altitude of 6,000 feet trend southwest, showing that the Yaak lobe penetrated into Idaho.

The main lobe entered Montana north of Eureka, crossed the Tobacco Plains to Black Butte, and at first it there split in two. One branch moved down the Kootenai Valley, the other up the Tobacco Valley. Subsequently, however, the intervening Salish Mountains were overridden at least as far south as Elk Mountain, where the thickened ice sheet was again split in two.

The branch that moved up the Tobacco Valley, then down the Stillwater and the lower part of the Flathead Valley seems to have been the largest and longest tongue, probably because it was moving in the largest and deepest valley, and for the greater part downgradient. Its terminal moraines lie south of Flathead Lake, at Polson,

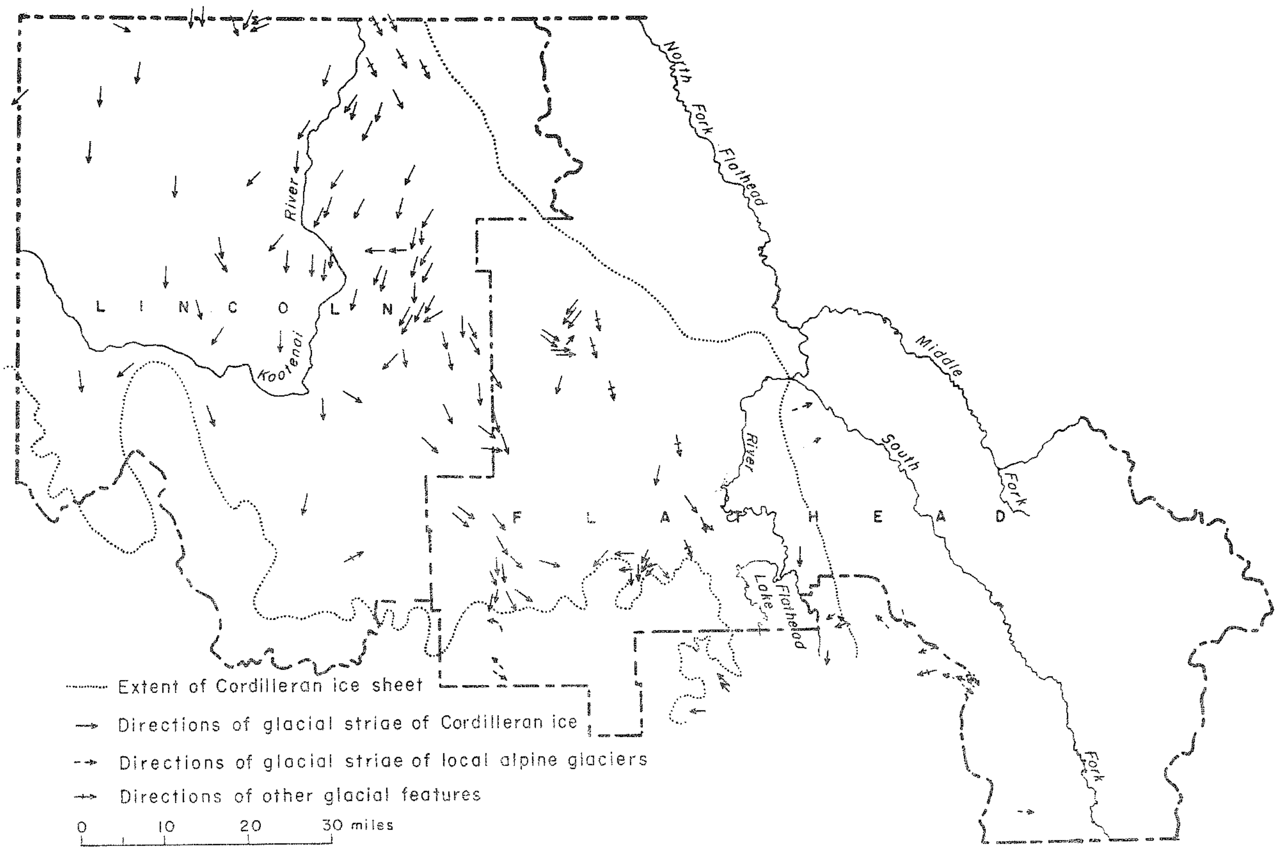


Figure 3.—Map showing extent and direction of movement of Cordilleran ice sheet and valley glaciers.

and west of the lake, west of Big Arm. Furthermore, it was augmented at Columbia Falls by glaciers that came down the valleys of North Fork and South Fork of Flathead River (Erdmann, 1944, p. 64) and near Bigfork by a large valley glacier that came down the Swan Valley.

As the main lobe moved down the Stillwater Valley it was crowded against the west flank of the Whitefish Range. East of the north end of Whitefish Lake, striae that trend S. 50 to 57° E. indicate that the ice diagonally overrode the south end of the range.

Alpine glaciers on the east flank of the Swan Range and on the west flank of the Lewis and Clark Range merged to form an intermontane glacier that moved northwest down the valley of the South Fork of Flathead River. Combining with valley glaciers that followed down the valleys of the Middle Fork and the North Fork Flathead River, the whole mass turned abruptly westward through Badrock Canyon to join the Flathead lobe of the Cordilleran sheet at Columbia Falls.

From Badrock Canyon to Lake Blaine, the ice was crowded against the west flank of the Swan Range. Faceting of the spurs on this part of the Swan Range has been attributed to glacial action (Davis, 1921, p. 89), but Konizeski, Brietkrietz, and McMurtrey (1968, p. 9) ascribed the spurs to recent fault movement.

Near the junction of the Swan and Flathead Valleys, south of Lake Blaine, is a strip characterized by low interconnecting ridges between small lakes locally termed "The Potholes". This area marks the confluence of the Swan Valley glacier with the Flathead lobe of the Cordilleran ice sheet. Alpine glaciers from the east flank of the north part of the Mission Range and from the west flank of the Swan Range coalesced to form one of the largest valley glaciers, which moved north-northwest down the Swan Valley.

Partly because of the local topography, but also partly because of the convergence with the valley glaciers along the east side of the Flathead Valley, a sublobe of the Flathead lobe was diverted to the southwest at Kalispell and moved up the valleys of Ashley Creek, Boorman Creek, Mount Creek, and smaller valleys. On the east side of the Flathead Valley, the ice sheet was forced to override the northern part of the Mission Range. Southward to a point near Mission Wells the crestline was beveled to a flat or smoothly rounded surface, now covered with glacial drift. From Mission Wells the ice margin descended diagonally across the west face of the Mission Range to the valley floor at Polson.

Whereas the Flathead lobe of the Cordilleran ice sheet moved almost if not quite continuously downgrade, being restricted only laterally, the western lobes were forced to move upgrade after reaching the Libby area. In moving up the valleys of Lake Creek, Libby Creek, Fisher River, and smaller drainages, their effectiveness as erosive agents decreased, their rate of advance was retarded, and the amount of debris deposited in the terminal moraines was relatively scant.

In the northwestern part of the area, early encroachment of the Cordilleran ice sheet restricted the extent and intensity of action by the alpine glaciers. In the Purcell and Salish Mountains, only those few peaks more than 6,500 feet high stood as nunataks. Farther southeast, the greater height of the mountains and the lower surface of the ice sheet permitted more extensive activity by alpine glaciers, which also persisted for a longer period of time here. In fact, one small remnant of a mountain glacier still remains on the northeast slope of Swan Peak, in the Swan Range, at an altitude slightly above 9,000 feet.

GLACIAL TOPOGRAPHIC FEATURES

Long stretches of the valley of the Kootenai River north of Warland and of the Yaak River valley were carved to a U-shaped cross section by the advancing lobes of the Cordilleran ice sheet. The lobe that followed the Tobacco-Stillwater-Flathead Valleys in the Rocky Mountain Trench probably eroded such a valley there, but subsequent filling with moraine, outwash, and alluvium produced a virtually flat valley bottom. Sublobes of this eastern lobe moved up the valleys of Good Creek, northwest of Kalispell, and of Ashley Creek, southwest of Kalispell, producing U-shaped valleys in their lower reaches.

Alpine glaciers produced many U-shaped valleys near the headwaters of small drainages. They are especially prominent in the Swan Range and the Lewis and Clark Range, where they started well above the present timber line. On the northeast flank of the Swan Range, good examples can be seen at Sand Creek, Fawn Creek, Sullivan Creek, Bunker Creek and its Middle Fork, Gorge Creek, and Little Salmon Creek. On the southwest flank of the Swan Range, the North Fork of Lost Creek, Bond Creek, and Hall Creek occupy U-shaped valleys.

An unusual feature on the North Fork of Lost Creek seems to be related to the erosion of U-shaped valleys. Ice moving down from Thunderbolt Mountain scoured a narrow terracelike surface high on the south side of the valley, at an altitude of about 5,500 feet. The flat area averages about 50 feet in width and extends for 2 miles or more. On the state geologic map a northwest-trending fault is shown in this position, but no evidence of a fault is apparent along the North Fork, on the divide north of Thunderbolt Mountain, or along Bunker Creek east of the divide.

The sublobe of the Flathead lobe that diverged northwestward at Dayton produced the narrow uniform sloping Dayton Bench. This flat surface trends west-northwest for a distance of 1½ miles. Waterworn and striated pebbles and cobbles, glacial erratics, and small mounds of drift are scattered over the surface. Curiously, the outcrops above the bench show no evidence of ice movement.

Cirques, like U-shaped valleys, are more numerous and more fully developed in the Swan Range and other high ranges in the southeastern part of the area than in the northwestern part. In the Salish Mountains, as far north as the latitude of Whitefish and Libby, however, cirques that developed at the head of Listle Creek and on other nearby drainages whittled Dunsire Point to a sharp horn. Even the peaks nearest the Canadian border are sculptured by cirques; Northwest Peak is surrounded by cirques, several of which contain lakes. The 7½-minute topographic maps published by the U. S. Geological Survey after our field work was completed show these features clearly. In fact, erosional features that are below the present timber line are more readily identifiable on the topographic maps than in the field.

The most conspicuous glacial constructional features are the moraines, especially those that block drainageways and impound lakes. By far the largest lake is Flathead Lake, but the moraines that retain it are outside the study area, at Polson and west of Big Arm. A sublobe of the Flathead lobe left a terminal moraine that confines the water in Lake Mary Ronan, and the city of Whitefish is built on a low recessional moraine that impounds Whitefish Lake.

Numerous mountain lakes lie behind moraines left by the valley glaciers or by the Cordilleran ice sheet, but not all mountain lakes originated in this way. Many are contained in cirques or in overdeepened stretches of the valleys. A moraine fills a low area on the divide at the northwest end of the Cabinet Mountains; Bull River flows southward to the Clark Fork but it no longer drains Bull Lake, which lies north of the moraine. Instead, the water from Bull Lake flows northward down Lake Creek to the Kootenai, near Troy. Similarly the site of Tally Lake seems to have once been the valley of Lost Creek, before a moraine was deposited at the southeast end of the present lake. The water from the lake, which is very deep, now flows northeastward down Logan Creek.

Few of the moraine-dammed lakes provide such conspicuous evidence of drainage diversion as do Bull Lake and Tally Lake, but there are other examples. The whole subject of the interrelationship of glacial erosion, glacial deposition, and drainage diversion is too complex for further consideration here, however.

Kettle holes, swales, and hummocky topography characteristic of ground moraine are noticeable west of the Stillwater River between Lost Creek and Kalispell (Alden, 1953, p. 123) and also east and north of Kalispell. Similar topography was observed in the Little Bitterroot Valley 2 miles south of Little Bitterroot Lake and also about halfway up Evers Creek 3 miles east of Johnson Peak.

Drumlins are numerous and prominent only in the valley of the Tobacco River. They trend southeastward up the valley from Eureka to the vicinity of Stryker, which is on the low divide between the Tobacco and the Stillwater drainages. One other elongate drumlinlike deposit was observed ¼ mile south of Tally Lake, about 15 miles northwest of Kalispell.

PLEISTOCENE GLACIAL LAKES

As the mountain glaciers and the lobes of the Cordilleran ice sheet advanced, the small quantities of meltwater were at first free to escape to the Columbia River drainage system, but eventually the lobe that came down the Purcell Trench into Idaho blocked the Kootenai Valley northwest of Troy and later the Clark Fork Valley northwest of Thompson Falls. Thereafter the meltwater was ponded behind these ice dams and probably some others, forming lakes; the largest was Glacial Lake Missoula, which also has been the most extensively studied. Although a major glacial lake may have been impounded in the same place earlier, possibly several times, only the last one is considered here.

Along its northern side, Glacial Lake Missoula was generally confined at least in part by the advancing ice, and as the water level rose by small increments, the valleys of the Clark Fork, Bitterroot, and Blackfoot Rivers and their tributaries were flooded. Each temporary level of the rising water is marked by a faint shoreline; these are plainly visible in the valley of the Clark Fork, especially on the hills east of Missoula. When the lake began to fill, the amount of meltwater was minimal, and later the area over which the water could spread increased greatly, hence the increase in depth was slow.

As the climate gradually ameliorated, the ice stopped advancing, and for a relatively long period the lake level was static. Presumably evaporation offset melting. A prominent terrace was locally developed at an altitude of about 4,100 feet (McMurtrey and others, 1965, p. 12). Continued warming accelerated the runoff, the lake filled to an altitude of about 4,200 feet, even though the ice may have been retreating slowly, and at last the water overtopped the ice dam. Once water started flowing over it, the ice dam could not long persist; it may have failed completely within a few days. Obviously, no shoreline markings could have developed as the water level fell. The effects downstream can hardly be visualized.

At its maximum, Glacial Lake Missoula was about 2,000 feet deep just above the ice dam and covered an area estimated at 3,300 square miles. If the maximum altitude of the water surface is assumed to have been 4,200 feet, the 4,200-foot contour on topographic maps would outline the extreme extent of the lake, except in areas that were still covered by ice when the lake was drained. Inasmuch as the ice dam was destroyed soon after the glacial retreat began, most of the area in Lincoln and Flathead Counties was still covered by ice, and therefore most of the lakebed silts that are found in that area were deposited in lakes other than Glacial Lake Missoula.

Lakebed deposits that are definitely assignable to Glacial Lake Missoula are widespread in the Little Bitterroot Valley, most of which is south of the study area. A terrace fill consisting of 20 feet of brownish-gray clay and silt was observed near Little Meadow Creek, which is east of Hubbart Reservoir. Scattered erratic blocks of quartzite and gneiss observed in the Niarada area below an altitude of 3,800 feet are ice-rafted material deposited in Glacial Lake Missoula.

Elsewhere in the study area, Glacial Lake Missoula could have extended far up the Thompson and Vermilion Rivers but even if these valleys were not filled with ice, the lake would have overtopped the divide only at maximum stage, and then only by about 200 feet at most. The long narrow depression occupied by McGregor Lake, Thompson Lakes, and others may have been an ice-marginal drainageway soon after ice retreat began, but perhaps not until after Glacial Lake Missoula had been drained.

Near the Idaho boundary, the altitude of the moraine that forms the divide between Lake Creek to the north and Bull River to the south is about 2,350 feet. If this moraine marks the southern limit of ice advance, then Glacial Lake Missoula would have flooded much or all of Lake Creek valley. The Bull River valley seems to have a U-shaped cross section clear to its junction with the Clark Fork, however. Confluent mountain glaciers moving down this valley may have confined Glacial Lake Missoula to the area south of the divide. Alternatively, the sheet ice may have continued down the valley of Bull River, and the moraine that now forms the divide may have been a late recessional moraine formed after a brief re-advance.

Although Glacial Lake Missoula may have flooded the valley of Lake Creek for a brief period, most if not all of the lakebed silt in the valleys of the Yaak and Kootenai Rivers and their other tributaries must have been deposited in a separate smaller lake that may have formed at a fairly late stage of glacial retreat. A deposit of horizontally bedded lacustrine silt, well exposed northeast of Libby, overlies glacial till and attains a thickness

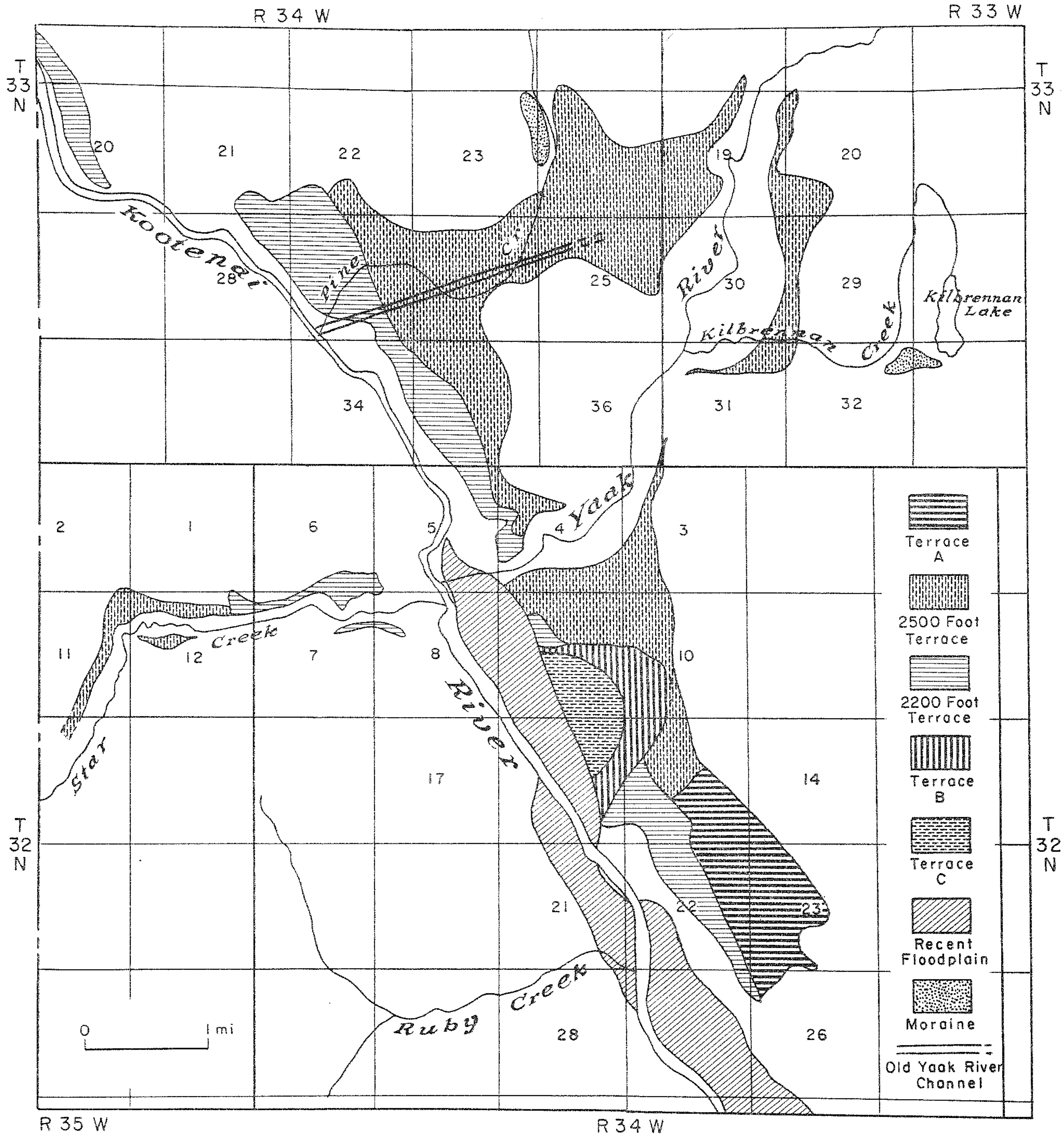


Figure 4.—Map showing terraces and flood plain adjacent to Star Creek and the Kootenai and Yaak Rivers. (After Dahlem, 1959.)

of 300 feet; other thick deposits of finely laminated silt are exposed east of Troy. In the Kootenai Valley northwest of Troy, massive silt deposits are found at altitudes of only 1,850 to 2,100 feet, whereas the altitude of the outlet of Glacial Lake Missoula after removal of the ice dam was about 2,200 feet. The lake that occupied the Yaak and Kootenai Valleys may have been impounded behind morainal material deposited by the lobe of ice that moved down the Purcell Trench, rather than behind the ice itself.

An implication that the lake in the Yaak-Kootenai Valley area was not released in a sudden flood by breaching of an ice dam but rather decreased by irregular erosion of a morainal dam of nonuniform composition is seen in the series of terraces near Troy. Two major terraces, at altitudes of 2,200 and 2,500 feet, border the Kootenai River west of Troy and also the Yaak River and Pine Creek for several miles above their junctions with the Kootenai (Fig. 4). Along the east side of the Yaak, at least six gravel-veneered terraces are visible below the 2,500-foot terrace. Two or more dissected terraces above the 2,500-foot terrace are less distinct. The series of terraces suggests that the Yaak-Kootenai drainage was graded to a lake that remained stable for long periods but periodically was lowered by rapid erosion of its outlet.

The present Flathead Lake is a remnant of a somewhat larger ancestral Flathead Lake that was impounded behind the terminal moraines of the lobe of Cordilleran ice that moved down the Flathead Valley. Lacustrine silt was deposited as far north as Columbia Falls and Whitefish in the main valley and almost to Marion in Ashley Creek valley. As the outlet at Polson was eroded deeper, the lake level was lowered; at present it is controlled by a dam.

After the ice sheet retreated beyond the Canadian border, glaciolacustrine deposits of fine silt and clay were spread over the morainal and outwash material on the broad plain north of Eureka and Rexford. As soon as the Kootenai Valley was free of ice the impounded water began to flow into the Kootenai River, and the Tobacco River began extending its headward reaches to the southeast (Sommers, 1961).

Lake Mary Ronan, like Flathead Lake, was formerly somewhat more extensive than it is now. Impounded water extended some distance up Hillburn Creek and other inlets, as shown by lake silt deposited over local accumulations of outwash. Silt deposits that formerly bordered the west shore of the lake have been removed by wave action, as the lake level fluctuates over a fairly large vertical range.

Numerous temporary high-altitude lakes persisted long enough to leave deposits of laminated silt and clay in the higher valleys. Silt in the valleys of Tepee, Squaw, and Harris Creeks, tributaries of Fisher River, was deposited in an ice-impounded lake that reached an altitude of 3,500 feet. Similar material is poorly exposed northeast of Loon Lake in Pleasant Valley. The overflow may have drained north down Swamp Creek for a while until the Fisher River was reopened.

Near the head of Seventeenmile Creek, northeast of Troy, deposits of stratified silt and clay at altitudes of 3,600 to 3,800 feet mark the site of a mountain lake, which probably was impounded by ice. The overflow may have spilled south into Quartz Creek or east into Pipe Creek; the divides are low and indistinct.

Lakebed silt and clay underlie Brown's Meadows, on Mount Creek about 6 miles south of its junction with Ashley Creek southwest of Kalispell. Part of this deposit is postglacial, however. The temporary glacial lake surface reached an altitude of about 4,300 feet, as indicated by the lake deposits, rather than 4,700 feet, as postulated by Alden (1953).

By their very nature, lakes are transitory features. It is not possible to categorize every lake in the area as ice-blocked or moraine-blocked, glacial or recent. Some of those that still contain water are obviously remnants of somewhat larger lakes that formed during glaciation. Those that are filled with sediment (as opposed to those that were drained by downcutting of the outlet) may be entirely glacial, entirely postglacial, or glacial to recent. Illustrative of the difficulty of classification is the situation near the head of Clay Creek, south of Yaak. There a deposit of glacial till containing rock flour, clay, silt, sand, and angular to subangular fragments of rock is reworked during each spring runoff; clay and silt are deposited downstream in a manmade lake.

STRATIGRAPHY

PRECAMBRIAN—BELTIAN ROCKS

A thick series of fine-grained clastic and carbonate rocks of late Precambrian age was named by Walcott (1899) the Belt Series for exposures in the Little Belt and Big Belt Mountains of west-central Montana. Previously the rocks had been described by Hayden (1869) and Peale (1873); Peale (1893) correctly assigned them to the Precambrian, on the basis of his work in the vicinity of Three Forks, Montana. Metasedimentary rocks of Precambrian age in northwestern

Montana are part of the Belt Series (Wilmarth, 1925, p. 104), as are similar rocks in northern Idaho, northeastern Washington, and southern British Columbia. In Canada the equivalents of the Belt Series are named the Lower and Upper Purcell.

GENERAL CONSIDERATIONS

The Belt rocks were deposited in a broad shallow depositional basin as sand, silt, and clay or a mixture (mud) and as carbonate. Regional low-grade metamorphism (quartz-albite-epidote-biotite subfacies of the greenschist facies) subsequently altered the clastic sediments to quartzite and argillite. The fine to very fined grained carbonate, supposedly deposited in deeper water, was recrystallized to dense impure limestone. Additional metamorphic effects noted include the formation of sericite, muscovite, biotite, and some magnetite.

The term "Belt Supergroup" was substituted for the term "Belt Series" by Childers (1963, p. 142). These Precambrian rocks have been subdivided into four major groups; in ascending order they are pre-Ravalli, Ravalli, Piegan, and Missoula Groups (Ross, 1959).

The lower part of the Belt is dominantly clastic; the Prichard Formation (pre-Ravalli) and the Ravalli Group are almost entirely argillite, siltite, and quartzite. The middle part of the Belt, represented by the Piegan Group (Wallace Formation in the western part and equivalent rocks in the eastern part of the area), is dominantly carbonate but its lower and upper parts contain much clastic material. Upper Belt rocks, that is, rocks of the Missoula Group, are again dominantly clastic, but subordinate carbonate-bearing strata occur in the group.

Thicknesses of all the groups vary, even within the map area, but the greatest changes observed were the northward thinning of the Ravalli and Piegen Groups from west-central Lincoln County to the International Boundary, and the eastward thinning of the Ravalli and Piegan Groups from the Salish Mountains to the Whitefish Range, across the Rocky Mountain Trench. The Prichard Formation (pre-Ravalli) is the thickest sequence in northwest Montana; in the Pend Orielle region of Idaho its thickness exceeds 20,000 feet.

The base of the Belt is nowhere exposed and the top is an erosional surface or (top of the Missoula Group) an unconformity with Middle Cambrian or younger strata. The total thickness of the Belt is therefore not determinable. In the western part of Lincoln County the thickness of exposed Belt rocks exceeds 40,000 feet. Farther east, in the Whitefish Range, the thickness exposed is 17,000 feet, and in the Lewis and Clark Range it is 25,000 feet. Farther south, in the central part of the Mission Range, it is 20,000 feet (Harrison and others, 1969).

In northwestern Montana, strata within the Belt are conformable. Structural deformation produced both tight and open folds having general northwest to north trend. Generally the intensity of folding decreases eastward from western Lincoln County to the trace of the Lewis Thrust in eastern Flathead County. Igneous rocks, including mafic dikes and sills and acid dikes and stocks, intrude all formations of the Belt Series. Mafic igneous dikes and sills were not observed in the Missoula Group in Lincoln County but were seen in Missoula rocks in southeastern Flathead County. A volcanic flow within the Belt sequence was first named by Daly (1912, p. 207) the Purcell Lava and later the Purcell Basalt (Wilmarth, 1938, p. 1746). It extends westward from Glacier National Park to the 115°30' meridian and from lat 48°30' in the southeastern part of the Whitefish Range northward into British Columbia.

All investigators of the Belt rocks describe abundant sedimentary features suggestive of shallow-water deposition and subaerial exposure, the most common features being ripple marks, cross-bedding and cross-lamination, mud-crack casts, mud-chip breccia, raindrop imprints, and salt-crystal casts. Smith (1963, p. 112) interpreted the rocks as alternating lacustrine or lagoonal sediments deposited in fairly deep quiet water during pre-Ravalli and Piegan time and lacustrine, fluviatile, and flood-plain sediments laid down in shallow turbulent water during Ravalli and Missoula time. He postulated a partly enclosed basin of Belt deposition, as sediment is inferred to have originated from sources to the northeast, south, southwest, and west. Barnes (1963, p. 51) concluded that quartz, feldspar, and clay minerals in Belt rocks of the Whitefish Range were possibly derived in most part from a high-grade metamorphic and plutonic terrain because he found composite quartz grains having crenulated crystal boundaries, which are characteristic of quartz derived from metamorphic terrains (Krynine, 1950, p. 48). Cross-bedding in quartzite beds is supporting evidence of a source area to the north or east.

The Belt basin of deposition was broad and shallow, and few permanent streams entered it. The surrounding regions were of moderate relief, and the climate was semiarid. Periodic influxes of water brought in fine sediment, which spread throughout the basin, probably distributed along a few very broad and shallow channels. The dried and mud-cracked surface around the margins was partly torn up and locally incorporated as mud chips in the basal part of the sediment that was being deposited. The finer sediment then settled, as influx subsided. As evaporation again exceeded influx, the surface eventually became cracked. Deeper portions of the lake probably remained covered by progressively more saline water while shallower parts emerged. The rate of subsidence probably approximated the rate of deposition; although no close balance between subsidence and sedimentation is required for such deposition, a balance is required to account for the persistence of shallow-water depositional structures throughout the sequence. The carbonate rocks of the Siyeh Formation may represent deposition in a deeper but still fairly shallow part of the lake, where detrital influx was less. The denser, more saline water resulting from evaporation would accumulate here and begin the deposition of dolomite (Barnes, 1963, p. 55). Harrison and Campbell (1963) described the basin as a trough trending northwest during deposition of pre-Ravalli, Ravalli, and Piegan rocks but trending northeast during deposition of Missoula rocks.

No doubt some parts of the Belt basin were somewhat deeper than other parts. On Yaak Mountain, northeast of Troy, the Wallace Formation includes several thousand feet of impure limestone, but these rocks grade laterally into clastic rocks containing only sparse carbonate. A local depression may account for the great thickness of these carbonate strata, which are strikingly similar to impure limestone beds of the Siyeh Formation.

Rocks in the lower two-thirds of the Belt are characterized by the predominance of various shades of gray, brown, white, and yellow, whereas rocks in the upper third exhibit red, purple, gray, and green hues. Rocks described as argillite in this report are more indurated equivalents of siltstone, claystone, mudstone, and shale (Twenhofel, 1937, p. 95). They contain clay- and silt-size particles and were not otherwise differentiated in reconnaissance field mapping. Quartzite and sandstone contain clastic grains ranging from very fine to coarse. In impure carbonate rocks the individual particles of carbonate minerals range from very fine to fine. All Belt rocks contain quartz as a constituent in various quantities.

Sericite in minute micaceous mats, shreds, and plates is discernible in all formations except the uppermost units of the Missoula Group, where, if sericite is present, it is sporadic (Libby Formation). This distribution of sericite is indicative of the decreased regional metamorphism of younger Belt rocks, particularly the upper units of the Missoula Group. Metamorphic features are most pronounced in the Prichard Formation. Phyllite interbedded with medium-grained white sericitic quartzite crops out on the flanks of the Sylvanite anticline north of Troy. These phyllitic rocks exhibit well-developed biotite folia, linear quartz, and sericite grains; the sericite where exposed on planar surfaces imparts a silky sheen to the rock. Some contact metamorphism related to a buried intrusive may have contributed to the schistosity exhibited by these rocks. In the eastern part of Flathead County, formations in the Missoula Group show less metamorphism than their Lincoln County equivalents; quartzite units are interbedded with siltstone, mudstone, and shale in the Whitefish and Lewis and Clark Ranges.

Detrital and secondary minerals of the Belt rocks are extremely variable in grain size, but few exceed 1.5 mm in diameter. Pyrite, garnet, and magnetite crystals are commonly megascopic, and by secondary crystal growth some grains attain large diameters; the larger crystals are almost confined to shear planes. Exceptionally large (a few centimeters) garnet and pyrite crystals and large (several millimeters) biotite and magnetite grains occur in the lower groups of the Belt. The principal accessory minerals are ilmenite, zircon, tourmaline, garnet, apatite, rutile, and epidote, but altogether they make up only a very small percentage of total rock constituents.

Argillite and quartzite of the pre-Ravalli Group (Prichard Formation) contain quartz, sericite, hematite, biotite porphyroblasts, pyrite cubes, and pyrrhotite grains and minute amounts of microscopic feldspar, carbonate, epidote, clinozoisite, zircon, ilmenite, leucoxene, rutile, garnet, apatite, chlorite, sericite, and tourmaline. Sericite makes up as much as 50 percent of some of the rock. Most of the quartz, zircon, apatite, and rutile originated as primary clastic minerals. Biotite, magnetite, and pyrite are both primary and secondary minerals. Epidote, carbonate, hematite, sericite, chlorite, and leucoxene are authigenic constituents. Grain size ranges from 0.01 to 1.5 mm, mean diameter being 0.04 mm. Many quartz grains exhibit interlocking characteristics and fused boundaries and are partly recrystallized; such grains are as much as 40 percent of some rocks. In eastern Lincoln County, apatite, zircon, and tourmaline occur in prismatic crystals as much as 0.1 mm long (Latuszynski, 1962, p. 23).

Carbonate strata in the upper Prichard Formation seem to thicken eastward from central Lincoln County.

Interbedded quartzite, argillaceous quartzite, and argillite of the Ravalli Group contain large percentages of quartz, but the purest quartzite contains only 86 percent silica. Particle size range for the quartzose rocks is between 0.01 and 1.0 mm or more, the average grain size being about 0.1 or 0.15 mm; in the argillite the mean diameter is about 0.05 mm. Small angular quartz particles are probably of detrital origin, whereas larger grains exhibit fused or welded boundaries indicative of secondary growth. Magnetite octahedra of both primary and secondary origin are pervasive throughout the Ravalli, the size ranging between 0.2 and 1.0 mm. Other minerals in rocks of the Ravalli Group include secondary sericite, leucoxene, and rare chlorite, carbonate, a moderate amount of biotite, and minor potash feldspar, plagioclase, zircon, apatite, epidote, ilmenite, tourmaline, and hematite. Dahlem (1959, p. 32) described magnetite particles in quartz, and Hall (1962, p. 29) found inclusions of quartz in magnetite granules, attesting to secondary growth of the quartz and of the magnetite, respectively. Biotite about 0.20 mm in diameter encloses crystals of quartz, zircon, and opaque minerals (Latuszynski, 1962, p. 28).

In the Wallace Formation, carbonate-bearing strata are sporadically distributed through the unit, but most of the impure limestone was observed near the central part of the formation. In the Piegan Group, of which the P_1, Siyeh, and P_3 units are the approximate eastern equivalents of the Wallace, the Siyeh Formation is everywhere carbonate bearing but the lower and upper Piegan units contain more argillite and quartzite and less carbonate.

Carbonate strata are almost everywhere impure, the major rock-forming minerals being calcite, dolomite, quartz, and sericite. Minor constituents make up about 5 percent of the rock. Grain size of carbonate minerals ranges from about 0.05 to 0.4 mm; angular and subrounded quartz grains range between 0.05 and 0.3 mm. The P_1 and P_3 units contain quartz, muscovite, sericite, chlorite, and minor amounts of feldspar, biotite, dolomite, zircon, and leucoxene. Cubes and grains of pyrite and limonite pseudomorphs after pyrite are common in Wallace and Piegan carbonate rock. Wampler and Kulp (1964, p. 1423) observed that forms of pyrite seen in modern sediments are also noted in lithified sediments, and they suggested that sedimentary pyrite reached its present crystalline state at the time of or soon after burial, but that disseminated euhedral crystals probably result from recrystallization during diagenesis. In the carbonate-bearing strata, chlorite is present in small amounts as are feldspar minerals. An uncommon weathering feature is associated with Wallace and Siyeh float and some outcrops—rock at the surface has been altered to red earthy pulverulent hematite, probably through oxidation of the ferrous iron in the rock. The altered shell surrounding unaltered pyrite-bearing carbonate rock attains a thickness of 2 cm or more.

Clastic rocks in the Missoula Group include quartzite, sandstone, argillite, claystone, and siltstone. Angular to subangular quartz particles are most abundant. Sericite, magnetite, ilmenite, specular hematite, and chlorite are found in the Striped Peak Formation. Ferruginous quartzose rocks of the Libby Formation in western Lincoln County are sporadically sericitic and contain some chlorite. Rocks above the Purcell Lava in eastern Flathead County contain quartz, muscovite, minor sericite, chlorite, iron oxides, feldspar, glauconite, barite, sparse biotite, epidote, zircon, magnetite, apatite, tourmaline, and carbonate.

The Shepard Formation is dominantly calcareous. Local discontinuous impure limestone beds occur elsewhere in Missoula strata in eastern Flathead County but carbonate rocks are relatively uncommon in the Missoula Group in western Lincoln County.

Ripple marks, mud-crack casts, flow casts, raindrop imprints, clay galls, mud-chip breccia, crossbedding, salt-crystal casts, scour-and-fill channels, graded bedding, and load casts are widespread throughout the Belt strata. These features aid in interpreting the geologic conditions under which the sediments were deposited. Ripple marks, mud-crack casts, scour-and-fill channels, crossbedding, graded bedding, and load casts also provide evidence helpful in determining the top and base of individual beds where overturning by structural deformation is suspected.

Throughout the Prichard Formation, relative sparseness of ripple marks, mud cracks, and crossbedding may indicate that the water was deeper than during deposition of Ravalli and Wallace sediments. Ravalli rocks, including the Appekunny and Grinnell Formations east of the Rocky Mountain Trench, exhibit current and oscillation ripple marks, mud-crack casts, crossbedding, and mud-chip breccia. In the Grinnell Formation, mud cracks are more common than ripple marks. Both the Wallace Formation and equivalent Piegan Group contain abundant ripple marks, clay galls (ovoid clay concretions), mud cracks, raindrop imprints, and cross-laminations. Mud-chip breccias are common in the P_1 unit but rare in the P_3 unit. Ripple marks are present in the more sandy units, whereas mud-crack casts characterize the argillaceous layers. Striped Peak and Kintla strata contain well-developed current ripple marks, mud cracks, mud-chip breccia, and sparse to abundant salt-crystal casts and raindrop impressions and sparse crossbedding. The Phillips Formation has moderately abundant ripple marks and mud cracks and some mud-chip breccia. Roosville strata also contain mud-chip breccia.

Mud cracks in the Wallace Formation of western Lincoln County are ¼ inch or less in depth. Undoubtedly the feature had been subsequently compacted by the weight of overlying rocks, but the short downward extension of the cracks may indicate that intervals of exposure to the atmosphere were very short before subsequent re-inundation.

Current ripple marks and oscillation ripples occur in the quartzite and argillaceous quartzite of the Ravalli, in the argillaceous beds of the Wallace and Piegan units, and in argillite and quartzite of the Striped Peak. In Ravalli rocks north of Elk Mountain west of the Rocky Mountain Trench, Gilmour (1964, p. 37) noted current ripple marks trending northwest. Near the Rocky Mountain Trench north of Olney, symmetrical and asymmetrical ripple marks in the P_1 formation range in trend from N. 30° W. to N. 10° E., the most commonly observed direction being about N. 15° W. A grid-type ripple mark consisting of one set of ripples superimposed on another set, the two sets intersecting at right angles, was observed in outcrop near Loon Lake north of Libby.

Crossbedding was best developed in the quartzite of the Ravalli and Striped Peak rocks. Graded bedding was rarely observed in outcrop. Scour-and-fill channels are sparse, and most were observed in the Ravalli Group. Mud-chip breccia is most abundant in the Piegan and Missoula Groups. A few load casts were observed in red argillite of the Striped Peak Formation. Barnes (1963, p. 42) described cross-lamination, load casts, mud-chip breccia, conglomerate, mud-crack casts, and sparse current ripples in the Roosville Formation in the eastern part of the Whitefish Range.

Previous to the development of radiometric age dating, the minimum age of Belt rocks was determinable only by stratigraphic and structural relationships with other rocks. In parts of western Montana the Flathead Quartzite (Middle Cambrian) overlies the youngest Belt rocks, thus fixing their minimum age.

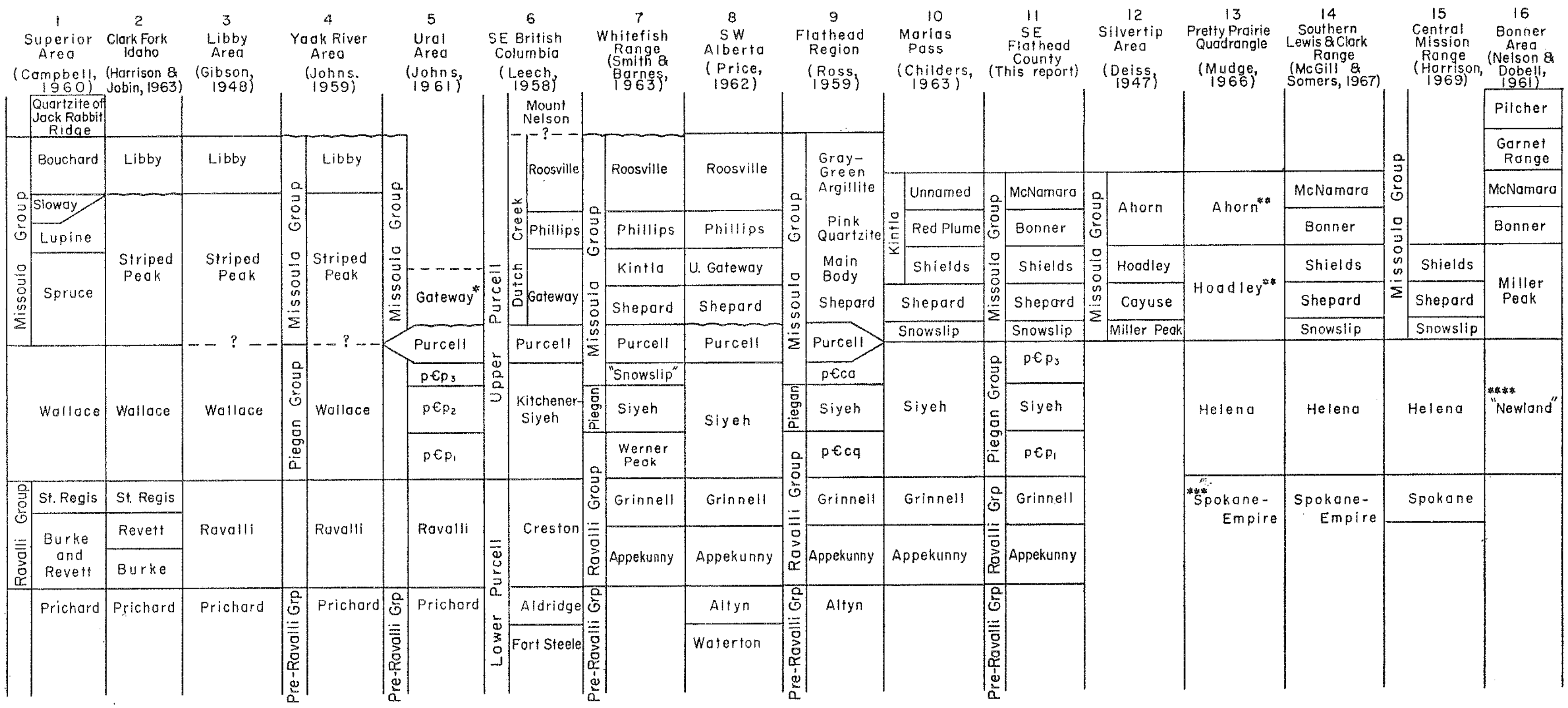
Radiometric age dating of ore deposits in Belt rocks in the Coeur d'Alene district, in the Sullivan mine in British Columbia, and other ore deposits in the northern Rocky Mountains provide figures for the age of Belt strata. In the Coeur d'Alene district, Eckelmann and Kulp (1957, p. 1129) analyzed specimens of pitchblende containing lead; they calculated the time of deposition as being between 1,100 and 1,200 m. y. ago. Long and others (1960, p. 653) determined a lead-isotope age of approximately 1,400 m. y. for certain Coeur d'Alene ores; Leech and Wanless (1962, p. 270) determined that lead in ores from the Sullivan mine in the Kimberly district left their source 1,250 m. y. ago; and Cannon and others (1962, p. 128) reported lead-isotope dates as old as 1,350 m. y. in the Coeur d'Alene district of northern Idaho and the East Kootenay district of British Columbia. Cannon believed that the wide range of ages from 1,350 m. y. to "future model ages" implies that the lead-zinc deposits of the Wallace Formation may have a geologic history different than that of the deposits in older Belt rocks (Prichard and Ravalli).

Glauconite from the upper part of the Belt, that is, within a few thousand feet below the Flathead Quartzite (Middle Cambrian), near Marias Pass in southeastern Flathead County, gave K-Ar and Rb-Sr ages averaging 1,070 m. y. (Gulbrandsen and others, 1963, p. 390). The age is regarded as a minimum for these Missoula Group strata. Wampler and Kulp (1964, p. 1443) determined that a sample from the Siyeh Formation that contains cubic pyrite enriched in lead corresponded to a Northern Pacific type lead of 1,250 m. y. Wampler (personal communication) expressed the opinion that this analysis indicates that the rocks cannot be much younger than 1,200 m. y. but that his isotopic data do not set a maximum age for the strata.

Barnes (1963, p. 48) interpreted certain radiometric age data as follows:

> "During the later [earlier?] stages of Belt deposition, about 1,400 to 1,500 m. y. ago, sills were emplaced and the Purcell Lavas [Basalt] were extruded. Later, about 1,250 to 1,400 m. y. ago, the Hellroaring Creek and associated granodiorite stocks [in British Columbia] were intruded and the Sullivan and Coeur d'Alene ore bodies were emplaced. Folding and faulting of the Belt strata probably took place at this time . . . and deposition of the Windermere System may also have begun. Later muscovites and biotites of the region lost argon, possibly as a result of increased pressure and temperature caused by burial beneath thick Paleozoic and Mesozoic sequences."

According to radiometric data, therefore, Prichard strata were deposited before 1,350 or 1,400 m. y. ago. The Siyeh Formation was deposited at least 1,200 m. y. ago, and strata in the upper part of the Missoula Group 1,150 or 1,170 m. y. ago. If these figures are correct, they indicate a long period of deposition and a subsequent long period of erosion during the time intervening between deposition of the uppermost Belt rocks now exposed and deposition of the Flathead Quart-



*Shelden (1961) describes the equivalent Gateway unit as the Shephard (Shepard) Formation.
**Mudge (1966) subdivides the Ahorn into two members and Hoadley into four members.
***Listed in order of decreasing age.
****Equivalent to the Wallace of the Coeur d'Alene mining district.

Figure 5.—Correlation of Belt strata (Precambrian) in northwest Montana, northern Idaho, and southeast British Columbia.

zite. Total thickness of Precambrian rocks deposited on top of the Missoula rocks but subsequently removed by erosion may have equaled the maximum thickness assigned to the Missoula Group or may have even exceeded it.

PRE-RAVALLI GROUP

PRICHARD FORMATION

The Prichard Formation was named by Ransome and Calkins (1908, p. 23) for a sequence of argillite and quartz-bearing argillite cropping out along Prichard Creek near Murray, Idaho. Prichard strata are exposed throughout Lincoln County and part of western Flathead County, where diastrophic movements elevated these strata sufficiently that they have now been exposed by erosion. The eastern extent of Prichard outcrop is along a boundary trending approximately northwest from Little Bitterroot Lake to the vicinity of Rexford.

A general distribution pattern of the Prichard Formation can be determined from Plates 1 and 2. Prichard strata tend to follow northwest belts trending obliquely across the map areas. Along parts of the Pinkham thrust in topographically low areas, Prichard strata form the hanging wall of the high-angle thrust, and their surface position is in part related to uplift of the western block. The formation comprises a homogeneous sequence of metasedimentary rocks. Ripple marks and mud cracks are sparse.

Nowhere in Lincoln and Flathead Counties is the base of the pre-Ravalli Group exposed. Thicknesses of Prichard strata reported in western Lincoln County range from 9,000 or 10,000 feet (Gibson, 148, p. 10; Johns, 1959, p. 8; and Dahlem, 1959, p. 14) to somewhat more than 12,000 feet in the core of the Sylvanite anticline in the Purcell Mountains (Johns, 1961, p. 13). Farther east in the eastern part of Lincoln and western part of Flathead Counties, only the uppermost part is exposed; 2,150 feet (Beer, 1960, p. 17), 1,500 feet (Shelden, 1961, p. 11), 4,000 feet (Hall 1962, p. 20), and 4,500 feet (Latuszynski, 1962, p. 19). Adjacent to Bitterroot Lake, only a few hundred feet of the uppermost Prichard Formation crops out west of the Pinkham thrust. Wallace and Hosterman (1956, p. 579) measured 17,000 feet of Prichard Formation along the Clark Fork River above its junction with the Flathead River. In the Pend Oreille area at least 22,000 feet is reported (Harrison and Campbell, 1963). Leech (1958) reported a thickness of 8,000 feet for the Aldridge and 6,000 feet for the Fort Steele Formation (equivalents of the pre-Ravalli Group) in the Purcell and Rocky Mountains of southern British Columbia (Fig. 5).

The color of fresh Prichard rocks in Lincoln and Flathead Counties is somber, ranging from dark to medium gray, grayish brown, blue gray, and grayish black for argillite and quartzitic argillite. Quartzite is light gray to white. On weathered surfaces, ferruginous Prichard strata are red brown to dark red or rusty colored as a result of oxidation of iron sulfides and biotite contained in the rocks.

Southwest of the Leonia fault and east of the Idaho boundary, about 9,000 feet of Prichard crops out. At the base of the exposed section, arenaceous to saccharoidal argillite is interbedded with shale; this sequence grades upward into a thick sequence of massive medium- to dark-gray argillite interbedded with quartzite. Quartzite becomes dominant toward the top of this sequence and is overlain by light-colored sandstone. The top of the exposed Prichard is an erosion surface, and the upper few thousand feet of laminated or thin-bedded sericitic argillite characteristic of the Prichard farther east and north is missing.

Prichard rocks in the Troy-Libby vicinity are medium bedded and thick bedded. In the Purcell Mountains about 1 mile south of Yaak Falls is a unit of dark-gray to grayish-black argillite containing streaks and irregular discontinuous masses of pyrite about parallel to bedding. A short adit was driven on the pyrite-bearing beds. The member was not observed east or southeast of this locality. Biotite porphyroblasts, flaky sercite, fine-grained muscovite, pyrite crystals, and pyrrhotite crystals and grains are common constituents of the quartzose beds.

In the Pend Oreille area of Idaho and the Superior region of Montana, Harrison and Campbell (1963, p. 1416) reported the Prichard Formation as divisible into three members: a lower member 19,000 feet thick consisting of interlayered gray-green argillaceous quartzite, gray siltite, and black and gray laminated argillite; a middle member 2,000 feet thick composed of laminated black and gray argillite; and an upper member 1,000 feet thick consisting of laminated black and gray argillite alternating with layers of slabby dark-gray siltite. A rusty weathered surface is produced by oxidation of small amounts of pyrite or pyrrhotite.

In the Libby quadrangle, Gibson (1948) described a 300-foot white to gray sericitic sandstone on Grouse Mountain 6,500 feet below the Ravalli contact, and Harrison and Campbell (1963) described vitreous lenticular zones of well-sorted quartzite 5,000 feet and 7,500 feet below the upper contact of the formation. At about the same stratigraphic position in the core of the Sylvanite anticline west of Yaak River is a zone of medium-

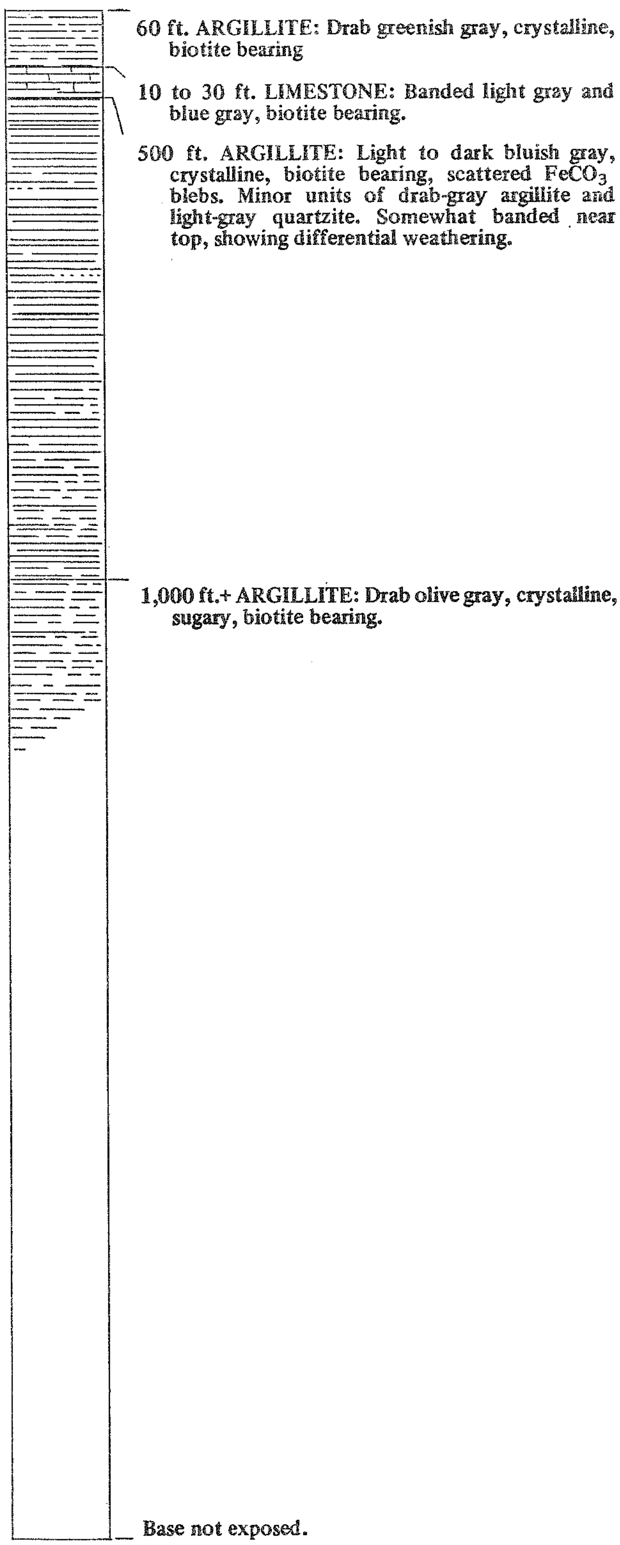


Figure 6.—Upper part of Prichard Formation, Pre-Ravalli Group, section on west slope of Elk Mountain in sec. 16 and 17, T. 31 N., R. 26 W. (After Galster, U. S. Army Corps of Engineers).

and thick-bedded white and very light gray sericitic quartzite interbedded with rusty-weathered grayish-brown quartzite, dark- and light-gray argillite, and phyllitic rocks containing sericite, biotite, and quartz. Leech (1958, p. 7) described the Fort Steele Formation underlying the Aldridge as consisting of white siliceous quartzite, gray argillaceous quartzite, dark argillite, and gray and black dolomitic and calcareous argillite and dolomite. The Fort Steele and Aldridge Formations total 14,000 feet in thickness and they are equivalents of the Prichard Formation.

South of Warland, the Prichard is medium- and dark-gray sandy argillite and quartzitic argillite, and east of Warland it is white argillitic sandstone.

In the Ural and Pleasant Valley areas only the upper few thousand feet of the Prichard is exposed. On Elk Mountain (Fig. 6) about 1,600 feet of gray, blue-gray, and drab olive-gray biotite-bearing argillite is present. Strata are interlaminated quartzite and argillite layers in tones of light gray, dark gray, and bluish gray; surfaces and joint and bedding planes display some red-brown weathering. A few mud cracks are present near the top of the unit. Toward the top of the formation the beds become more quartzitic, but below the Prichard-Ravalli contact there is a calcareous zone about 500 feet thick containing silty interbeds of calcareous argillite and limestone. Carbonate rocks in the zone weather light gray and exhibit a pitted surface from leaching of calcite and carbonate-bearing laminae. Carbonate-bearing rocks at this stratigraphic position were recognized in the Thompson Lakes and Ural areas.

Along Vermilion River in the vicinity of Lyons Gulch is a thick white quartzite overlain by rusty-weathering interlaminated gray argillite and white quartzite. Similar rocks crop out along the Yaak River northeast of Pine Creek. Above this sequence is thick-bedded light-colored sericitic quartzite and argillite that exhibits no rusty weathering. In both localities, the base of the quartzite is regarded as the contact between the Prichard and Ravalli. Elsewhere in the area discussed in this report, there is a transitional zone, and the contact was placed at the midpoint of the zone, because poor exposures in many areas precluded the possibility of locating the uppermost argillite bed with any accuracy. In the Yaak River area, the width of the outcrop of the transitional zone ranges from 300 to 500 feet, but at Wolf Creek it is much wider, and in the Thompson Lakes area it is 500 to 800 feet wide. In the Ural area, it is 500 to 600 feet wide, and farther east in the Elk Mountain vicinity it is also 500 feet wide.

In the McGregor Lake area, however, it is 700 to 800 feet wide. The average width of outcrop of this gradational zone is about 575 feet, which is greater than the true thickness of the sequence.

Transitional zones at the top of the Prichard Formation have been described from a minimum of 300 feet to over 2,000 feet wide in the Coeur d'Alene district and adjacent areas (Hobbs and others, 1965, p. 34). In the Coeur d'Alene district the contact between the Prichard and overlying Burke Formations is arbitrarily placed at the top of the highest laminated argillite in the zone.

If the rate of Belt deposition was 10 cm per 1,000 years as for the Green River Formation (Bradley, 1929, p. 99, 108), as suggested by Smith (1963, p. 114), the time required for deposition of the gradational zone was 1½ to 1¾ million years, or half again as long as the Pleistocene epoch.

Prichard beds exposed southwest of the Leonia fault are believed to be correlative with part of the Fort Steele Formation of the Western Canadian Rockies. Prichard strata exposed west of Yaak River are believed to be correlative with both Aldridge and Fort Steele Formations. Most remaining Prichard strata in the map area are correlative with the upper part of the Aldridge of southern British Columbia and with the upper member and part of the middle member of the Prichard Formation in the Pend Oreille area as described by Harrison and Campbell (1963).

Carbonate-bearing strata in the Pleasant Valley area within the uppermost Prichard may indicate a westward wedging out of the carbonate-bearing Altyn Formation of Glacier National Park. The Newland of the Canyon Ferry area and the Belt Mountains is correlated with Prichard strata by M. R. Mudge (personal communication).

RAVALLI GROUP—WESTERN PHASE

Walcott (1906, p. 7) first used the term "Ravalli Series" for a thick sequence of purple, gray, and greenish-gray beds underlying his Blackfoot Series in the Mission and Swan Ranges and adjacent areas. The Ravalli was named for the town of Ravalli, where the rocks crop out in hills along the Jocko River in southern Lake County (Wilmarth, 1938). Calkins and MacDonald (1909, p. 37) used the term "Ravalli Group" to designate a thick sequence of light-colored rocks ranging in composition from pure white quartzite to siliceous argillite containing some gray, green, purple, and red beds. This group underlies the Wallace and overlies the Prichard Formation in their map area, which includes the Purcell, Cabinet, and Bitterroot Mountains, and extends westward to Coeur d'Alene Lake and eastward to Ravalli.

In the Coeur d'Alene district of Idaho, the Ravalli Group includes the Burke Formation, Revett Quartzite, and St. Regis Formation (Calkins and MacDonald, 1909, p. 37). Gibson (1948, p. 12) described the Ravalli Formation in the Libby area as gray and white quartzite, which he stated could be identified as the equivalent of the Revett Quartzite of the Coeur d'Alene district.

West of the Rocky Mountain Trench, undifferentiated Ravalli quartzite and argillite (Western phase) consists of a homogeneous sequence of gray, white, green-gray, and bluish-gray quartzite and argillite, in which detailed mapping may permit a threefold division as suggested by Shelden (1961, p. 16), Hall (1962, p. 28), and Page (1963, p. 9).

Undifferentiated Ravalli strata as here described are confined, within the map area, west of a line that approximately parallels the west side of the Rocky Mountain Trench from the vicinity of Rollins, past Blacktail Mountain, west of Johnson Peak, to the International Boundary (Pl. 2). The strata are well exposed along the Vermilion River road northeast of Lyons Creek, along the Yaak River road northeast of Pine Creek, along Montana Highway 37 northwest of Dunn Creek, east of Little Bitterroot Lake, and in the vicinity of Brush Pass on the crossover road from Sheppard Creek to Wolf Creek.

The thickness of the Ravalli beds is variable. In the Libby district, Gibson (1948, p. 12) reported the Ravalli to be about 10,000 feet thick. In the Yaak River vicinity about 7,000 feet of Ravalli beds crop out northeast of Pine Creek, and about 11,500 feet of Ravalli was graphically scaled where the formation crosses Seventeenmile Creek. In the Thompson Lakes area the Ravalli is 7,070 feet thick. A 15,000-foot section southeast of Warland is not representative; it results either from local thickening or from fault repetition. To the north (north Purcell Mountains) the Ravalli Group thins to about 4,500 feet thick. In Pleasant Valley, the Ravalli Formation is about 10,000 feet thick, east of Little Bitterroot Lake between 9,000 and 11,500 feet crop out. On Elk Mountain, Richard Galster measured about 8,400 feet of beds that he assigned to the Ravalli Group. (Fig. 7).

Within central and western Lincoln County the Ravalli Group is medium-gray, bluish-gray, and white quartzite, argillite, and quartzitic argillite. In north-central Lincoln County and western Flathead County light-colored strata are most common, but green-gray and medium-dark-gray

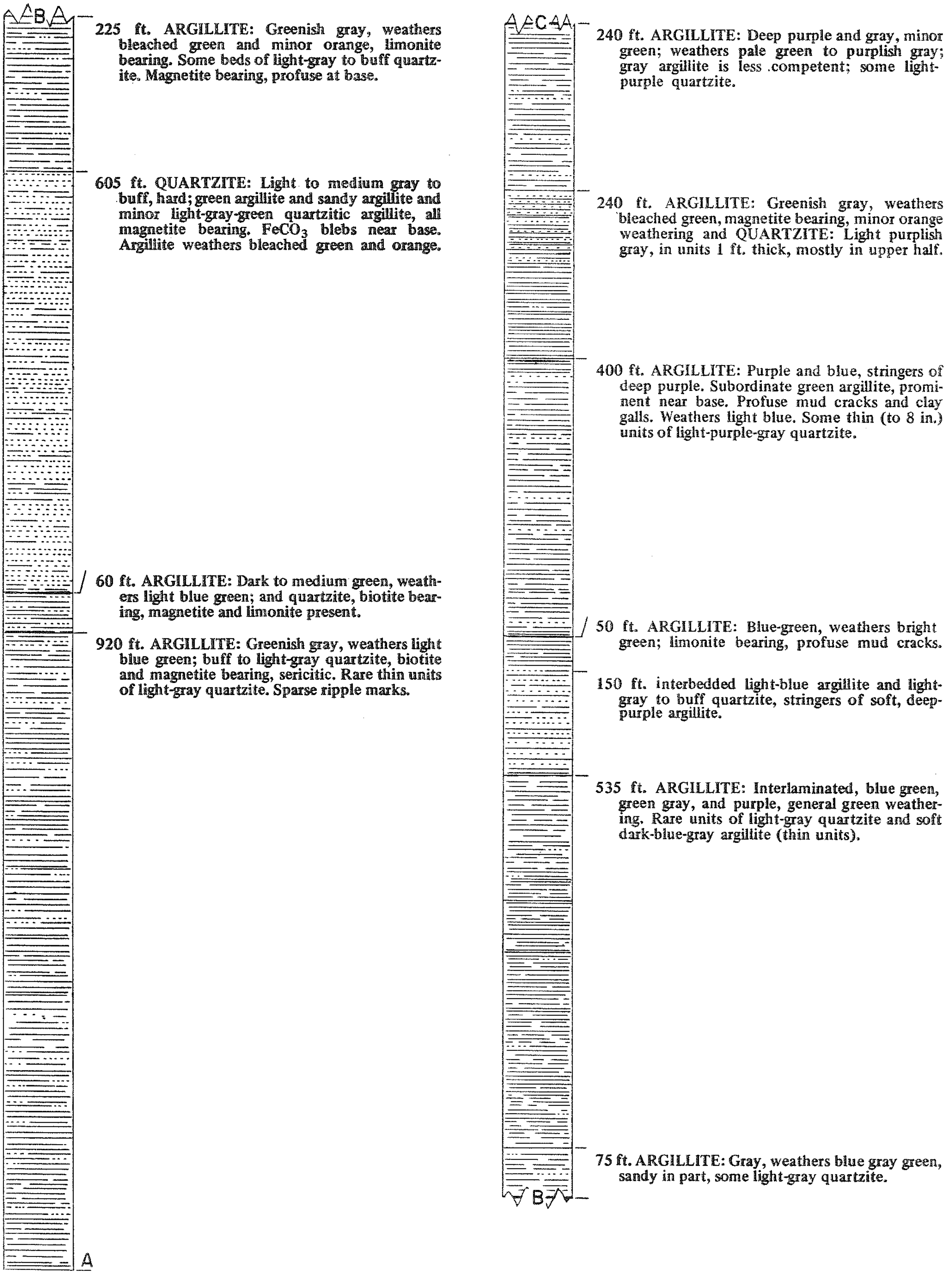
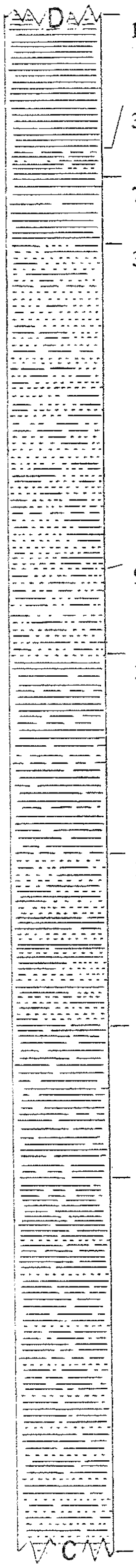


Figure 7.—Ravalli Group undifferentiated, section on Elk Mountain in sec. 10 and 16, T. 31 N., R. 26 W. (After Galster, U. S. Army Corps of Engineers).



140 ft. ARGILLITE: Green, siliceous in part, weathers rusty orange; mud cracks.

30 ft. ARGILLITE: Green and purple banded; minor light-purple quartzite and dark-gray argillite.

70 ft. ARGILLITE: Light-blue-gray, magnetite bearing, pyrite weathers to limonite.

340 ft. QUARTZITIC ARGILLITE and QUARTZITE: Banded light gray, minor purple, and blue in units several feet thick separated by purple to blue-gray noncompetent argillite and rare thin beds of white quartzite.

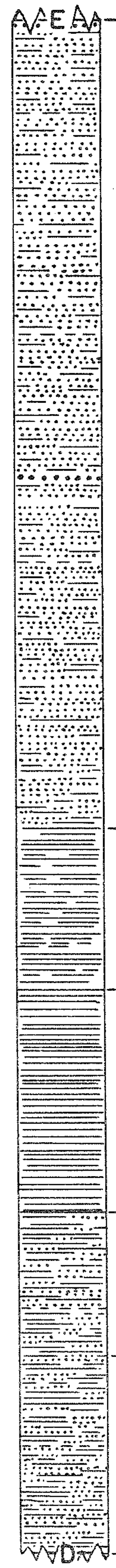
90 ft. QUARTZITIC ARGILLITE: Gray to olive green, weathers bleached green; light-gray to purple banded quartzite. Crossbedded, 5-ft. crossbedded light-gray quartzite at base.

210 ft. ARGILLITE: Mottled green, purple, and blue gray; partly noncompetent; minor orange weathering near base due to profuse limonite.

180 ft. Laminated QUARTZITE: Light bluish gray, crossbedded, and ARGILLITE: Drab greenish gray and blue gray, quartzitic in part.

160 ft. ARGILLITE: Gray to olive drab, some dark-blue-gray stringers; weathers light blue to light green.

390 ft. ARGILLITE: Laminated dark blue gray, purple, and pale green, profuse mud cracks, and QUARTZITE: Light gray and purple, banded, makes up ½ of 3-ft. units near base but less prominent upward; absent in top 60 ft.



900 ft. QUARTZITE and QUARTZITIC ARGILLITE: Light purple, light blue gray, and light gray, crossbedded. Distinctive marker beds at top and 500 ft. below top consisting of white sedimentary quartz in light-purple quartzitic argillite. Minor dark-purple argillite (weak), thin bedded in units 3 ft. thick or less.

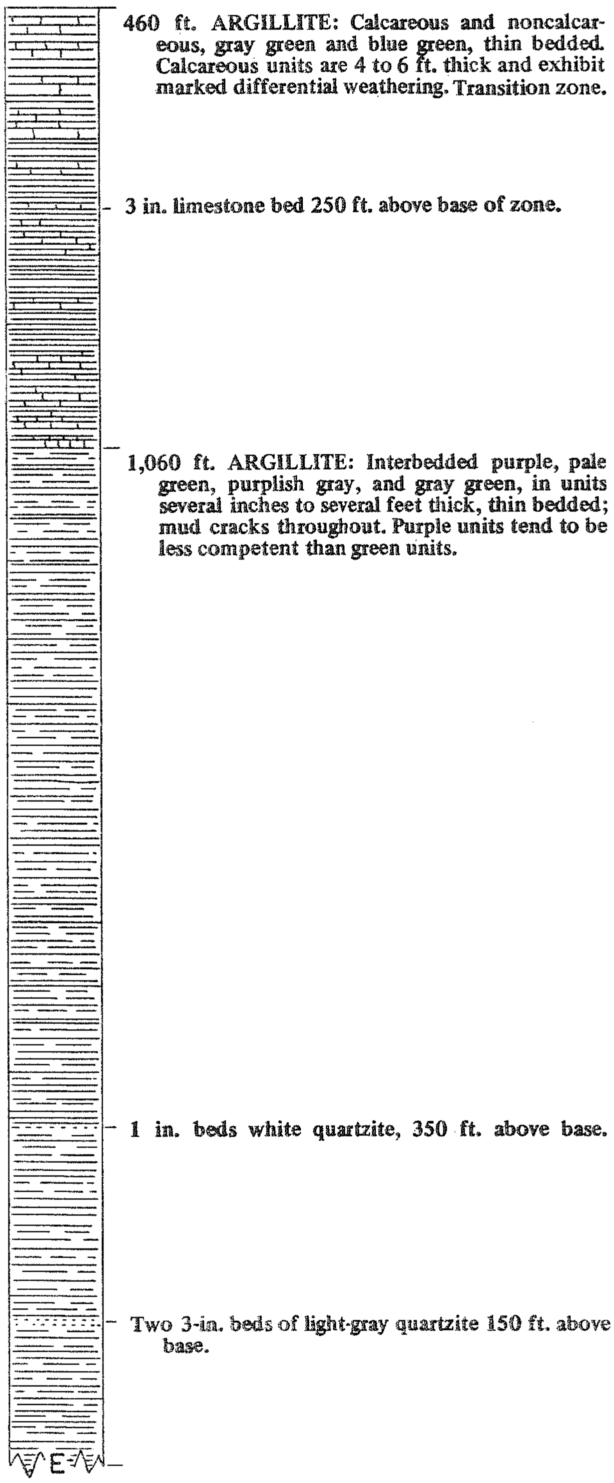
Mud cracks common near base only.

180 ft. ARGILLITE: Interbedded green and purple in units 2 to 3 ft. thick. Mud cracks common.

250 ft. ARGILLITE: Banded light and dark green.

380 ft. QUARTZITIC ARGILLITE: Light purple and light green; thin beds of purple QUARTZITE: Green argillite common at base, less so near top, where it occurs in units several feet thick and 30 to 60 ft. apart.

1 ft. pale-gray-green quartzite 160 ft. below top. Some light and dark-purple argillite.



tones are more prominent in the lower and middle parts of the group. Nearer the trench, reddish-purple and purple tones are apparent in the upper part of the sequence.

Ravalli rocks are dominantly siliceous and range from laminated to thick-bedded quartzite, quartzitic argillite, and argillite. Variable amounts of euhedral magnetite are distributed throughout the group, and sparse cubic pyrite and biotite are disseminated as megascopic euhedral crystals within the basal part of the formation. Some ilmenite was reported by Beer (1960, p. 28) in thin sections examined petrographically. Near the contact with the overlying Wallace Formation, in the Thompson Lakes and Warland areas, occur minor white and medium-dark-gray spherical to elongate structures resembling hieroglyphic writing. The pods are believed to have the same composition as the groundmass in this area, although the forms differ in color from the rock mass.

Where dips are flat to moderate, resistant beds in the Ravalli crop out as cliffs and ledges; talus slopes are prominent at the base of high cliffs. Occasional ferruginous beds exhibit red and purple tints. Crossbedding in sandy members, mud cracks and ripple marks in more argillaceous members, and some mud-chip breccia are present in the sequence.

The contact zone between the Ravalli and the overlying Piegan Group is comformable and gradational. In the transitional zone, which is 100 to 300 feet thick,* the contact was placed where the noncalcareous blue- or green-toned gray and grayish-white quartzite and argillite sequence is overlain by carbonate-bearing light- and dark-green argillite of the Piegan Group.

Possibly several hundred feet of St. Regis beds, consisting of noncalcareous greenish-gray argillite, crop out below the Wallace south of Vermilion River (Calkins and MacDonald, 1909). This upper Ravalli unit was not recognized northwest of Vermilion River, and it is believed that the facies changes northwest of this locality.

In the eastern part of Lincoln County and the western part of Flathead County the conformable lithologic units consist of a basal member of very thin-bedded to thick-bedded green and greenish-gray argillaceous quartzite and argillite about 2,000 feet thick, a middle member of thin- to thick-bedded dark-gray to very light gray quartzite and argillite 4,000 to 4,500 feet thick, and an upper unit of thin- to thick-bedded light-gray to white crossbedded quartzite with purple tones, which is approximately 2,000 feet thick.

Rock from the upper part of the Ravalli southwest of Olney has been described in more

* A transitional zone more than 800 feet thick, which is exposed in the Pleasant Valley-Fisher River area, was mistakenly identified as the transition zone between Ravalli and Piegan (Johns, 1960, p. 9). It is actually the transitional zone between Prichard and Ravalli strata.

detail as consisting of about 70 percent silt and 30 percent clay. A small percentage of very fine sand occurs in the basal parts of microscopically graded laminae; the upper parts are medium silt. Scattered in these laminated beds are some rounded intraformational pebbles of clay-sized material, similar in general appearance to the clay between the graded laminae. As seen in thin section, these pebbles seem to be imbricated, as are the accompanying mica flakes and a few quartz grains, and thereby indicate a southeast direction of the transporting medium, possibly offshore currents. Rare composite grains of quartz are subangular and contain well-rounded grains of quartz, indicating that the composite grains were derived from a pre-Ravalli sedimentary rock in which well-rounded quartz grains had been cemented by quartz (Gilmour, 1964, p. 23).

RAVALLI GROUP—EASTERN PHASE

APPEKUNNY FORMATION

The Appekunny Formation, the bottom unit of the Ravalli Group, was named by Willis (1902, p. 322) for exposures on Appekunny Mountain in Glacier National Park. The unit is approximately 2,000 feet thick and consists of finely laminated gray-green argillite and gray-white massive quartzitic sandstone. Unlike the Prichard, the Appekunny contains virtually no biotite. Mud cracks and ripple marks are common throughout the unit.

An incomplete section of the Appekunny Formation is exposed in the southern part of Whitefish Range, along the west flank of the northern part of the Swan Range, and on the east slope of the Mission Range. The section at Diamond Peak in the Whitefish Range exceeds 3,000 feet in thickness, and 4,500 feet of Appekunny is exposed in the Swan Range.

Appekunny argillite exposed in the southern part of the Whitefish Range is gray green to shades of gray but weathers yellowish gray and rusty brown. Smith (1963, p. 20) attributed the red-brown weathering color to oxidation of pyrite.

Near Swan Lake the Appekunny is a thin- to thick-bedded light-gray and purplish-gray argillite showing local greenish-gray tones. Interbedded with the argillite is some white coarse-grained feldspathic quartzite. On weathered surfaces the argillite is light gray to purplish gray. Octahedral magnetite crystals are sporadic in the unit.

The lowest Appekunny rocks exposed on the northeast side of upper Whitefish Valley are light-gray siliceous argillite, flaggy to slabby, and weathering to orange-brown, yellowish-gray, or brownish-gray tones. Some alternating light-gray and dark-gray argillite laminae were noted in this lower sequence. Overlying these beds are light-gray or light-greenish-gray fine-grained quartzite interlayered with medium-gray argillite. This upper part is 3,000 feet thick and weathers pale yellow gray.

In the northern part of the Swan and Mission Ranges, the Appekunny is predominantly light-gray to purplish-gray and greenish-gray siliceous argillite. Quartzite interbeds are light gray to white.

On the west slope of the Mission Range, a few miles south of Bigfork, the Appekunny Formation is no longer distinguishable. Farther south it is mapped with the overlying strata as Ravalli undifferentiated.

The top of the Appekunny, which is light-gray and greenish-gray fine-grained quartzite that weathers pale yellowish gray to purplish gray, is in gradational contact with the base of the overlying Grinnell Formation, which is gray-red-purple fine-grained argillite, light-gray quartzite, and minor interlaminated green-gray argillite.

GRINNELL FORMATION

This formation was named the Grinnell Argillite by Willis (1902, p. 322) from exposures on Mount Grinnell in Glacier National Park, where it comprises about 1,800 feet of gray, purple, and red argillite interbedded with some white quartzite. The Grinnell Formation is exposed in the Whitefish Range, along the west flank of the Swan Range, in the northern part of the Mission Range, and between Rollins and Dayton on the west shore of Flathead Lake. A short distance south and northwest the Grinnell beds lose their identity and are mapped with the underlying beds as Ravalli undifferentiated.

In the Whitefish Range the thickness of Grinnell beds is estimated to be 2,500 feet. In the north part of the Mission Range the Grinnell Formation is 3,500 feet thick, but it thins rapidly south of Crane Creek, and farther south it is no longer a mappable unit. To the east, in the Swan Range, the Grinnell thickens to at least 4,600 feet.

In the western part of the Whitefish Range, the Grinnell Formation is grayish-red-purple to purplish-gray laminated, mud-cracked, generally noncalcareous, micaceous, indurated siltstone interbedded with similar greenish-gray siltstone. Interlayered with both types of siltstone are beds of white, fine- to coarse-grained quartzite as much as 1 foot thick. Many of the quartzite beds are cross-bedded, and some contain mud chips derived from the underlying beds (Smith, 1963, p. 34).

In the eastern part of the Whitefish Range, the Grinnell Formation is medium light-purplish-gray coarse-grained argillite, grayish-red-purple fine-grained mud-cracked argillite, interlaminated greenish-gray and blue-green and grayish-red-purple argillite, interbedded with light-greenish-gray and greenish-gray siltstone. Light-gray fine- to medium-grained quartzite and quartzitic sandstone are interbedded with the argillite (Barnes, 1963, p. 11).

In the Mission and Swan Ranges, the Grinnell is predominantly gray-red-purple to grayish-red argillite containing intercalated beds of calcareous grayish-green argillite. Thin beds of coarse-grained white feldspathic quartzite are intercalated with argillite in the upper part of the Grinnell Formation.

The Grinnell grades through a transitional zone several hundred feet thick into the overlying P_1 unit, but on the basis of weathered surfaces, sedimentary structures, and color, the contact can be placed within a "few tens of feet" in the eastern part of the Whitefish Range (Barnes 1963, p. 17).

The conformable contact between the Grinnell Formation and the overlying P_1 unit is drawn where predominantly gray-red and gray-red-purple argillite is overlain by predominantly gray-green, pale-blue-green, and pale-green slightly calcareous argillite.

Ravalli rocks are believed to be correlative with the Appekunny and Grinnell Formations of eastern Flathead County, with the Creston Formation of southeastern British Columbia, and with the Spokane and Empire Formations in the Lewis and Clark Range. On the basis of lithologic descriptions and stratigraphic position, the Burke-Revett and St. Regis Formations of the St. Regis-Superior area and the Burke, Revett, and St. Regis Formations of the Pend Oreille area are equated with Ravalli rocks in Lincoln and Flathead Counties, but the Burke and St. Regis lithologies were not recognized as distinct mappable units in Flathead and Lincoln Counties.

PIEGAN GROUP—WESTERN PHASE

Fenton and Fenton (1937, p. 1890) proposed the name Piegan Group for a sequence of limestone, dolomite, and dominantly argillaceous clastic rocks lying between the Missoula and Ravalli Groups, as redefined by them, and designated a type locality at Piegan Mountain in Glacier Park. The thickness was stated to be 2,780 to 14,300 feet. Ross (1959, p. 33) redefined the group to include only the Siyeh Limestone. He retained the group name to facilitate broad correlation of this group, which is characterized by its carbonate content. Ross assigned an underlying transition zone (P_1 unit in this report) to the Ravalli Group, and he placed an overlying one (P_3 unit in this report) in the Missoula Group. In this report the western phase of the Piegan Group is represented by the Wallace Formation, as defined by Gibson in the Libby quadrangle (1948, p. 13), but the eastern phase includes three mappable units, the Siyeh Limestone and the transitional beds below and above the Siyeh.

WALLACE FORMATION

Ransome (1905, p. 282) named the Wallace Formation for exposures near Wallace, Idaho, and described it as comprising three parts, a lower gray-green calcareous argillite, a middle sequence of ferruginous blue-green argillite, limestone, and light-gray and white calcareous quartzite, and an upper laminated blue-gray, gray-green, and white argillite. The upper unit is fairly homogeneous and calcareous.

Gibson (1948, p. 14) described the Wallace in the Libby area as the most heterogeneous formation of the Belt Series. There the main constituents are calcareous or dolomitic argillite and shale, but the formation contains also some sandstone and small amounts of dolomite and dolomitic limestone. The upper third of the formation is sandy sericitic and ferruginous shale a few hundred to a thousand feet thick. This part resembles the overlying Striped Peak rocks but can be distinguished from them by a less consistent lithology.

In western Lincoln County, basal Wallace rocks include argillite interbedded with quartzite grading upward into argillite containing subordinate limestone and dolomitic limestone. Locally, a thick sequence of magnesian limestone near the center of the formation is exposed on Yaak Mountain. Upper Wallace beds are characterized by sericitic argillite and limestone; minor quartzite is local. Algal zones and molar-tooth structures are associated with the Wallace. Secondary cubic pyrite and limonite pseudomorphs after pyrite are common in the more calcareous parts of the formation.

Wallace strata are extensively exposed throughout western Lincoln County (Pl. 1) where they conformably overlie the Ravalli and underlie the Striped Peak Formation. Southwest of Troy, upper Wallace strata are in fault contact with Prichard strata along the Leonia fault.

Several northwest-trending belts of Wallace rocks are exposed south and southwest of Libby and northwest of Thompson Lakes. Lower and middle Wallace rocks west of a line just east of Mt. Henry are not subdivided, but farther southeast the equivalent strata can be subdivided into the three units of the eastern phase of the Piegan

Group. The western phase of the Piegan Group (Wallace Formation) merges into the eastern phase (P_1, Siyeh, and P_3) along a line trending southeast from the International Border at long 115° 35' through Mt. Henry, Lawrence Mountain, Hornet Ridge, and Meadow Peak, then south to the Thompson River.

The thickness of the Wallace Formation ranges from about 8,000 to 15,000 feet or possibly more. Gibson (1948, p. 13) reported a thickness of 12,000 feet on Mount Berray and 16,000 feet on Snowshoe Peak, and suggested that the unit may be as much as 17,000 feet thick in the vicinity of Mount Sheldon.

Southwest of Troy, Dahlem (1959, p. 37) observed at least 10,000 feet of Wallace, and farther north a graphically scaled section along Seventeenmile Creek measured about 14,000 feet thick. South of the International Boundary a graphically scaled incomplete section was about 11,000 feet thick.

Graphically measured sections in the Thompson Lakes area ranged from 11,000 to as much as 14,000 feet in thickness. Beer (1960, p. 31) reported an incomplete section (measured several miles southwest of the Kootenai River-Fisher River junction) that amounted to 15,050 feet in thickness.

Bedding plane faults and other, discordant faults, some too small to plot on the scale used for mapping, occur throughout the unit. Repetition of beds by faulting and also overthickening by folding may exaggerate calculated thicknesses of the Wallace, but the average thickness is believed to be about 12,000 feet.

Lithology of the Wallace Formation is heterogeneous multicolored rocks exhibiting subtle to marked change in mineral composition and texture. In the Libby area the most abundant rock is green-gray calcareous and sandy argillite and siltstone containing dark and light-colored laminae; some of the rock breaks across planes of stratification. Less abundant gray and brown quartzite and sandstone are interbedded with argillite. Lenticular impure dark- and light-gray limestone, magnesian limestone, and white impure dolomite commonly exhibiting segregation and molar-tooth structures are characteristic of middle Wallace strata but are not confined to it. Upper Wallace beds consist of gray and green calcareous and mottled argillite and siltstone, lenticular gray impure limestone, and local sequences of gray-red argillite and quartzite interbedded with green-gray argillite.

Elsewhere in western Lincoln County (Troy, Yaak, Rainy Creek, and Thompson Lakes areas) lower Wallace strata are dark- to light-gray, green, yellowish-green and blue-gray carbonate-bearing, laminated, thin- and medium-bedded argillite, siltstone, and subordinate gray and white quartzite, more sandy and quartzose near the base. Middle Wallace rocks are thin- and medium-bedded dark- and light-gray, green, yellow-green, and blue-green sandy and calcareous argillite and siltstone interlayered with dark- and medium-gray and blue-gray medium- and thick-bedded, pyritic impure magnesian limestone. Molar-tooth and segregation structure is conspicuous in the carbonate zones. Upper Wallace strata are dark- to light-green and gray, blue-gray, and yellow-green non-calcareous and calcareous laminated to medium-bedded argillite, siltstone, and quartzite interbedded with gray and white carbonate rocks containing white stromatolite zones 1 to 10 feet thick. Locally, greenish-gray laminated argillite and interbedded sequences of grayish-red argillite and quartzite in these upper Wallace beds could be confused with Striped Peak rocks. East of Pipe Creek Divide near Flatiron Mountain a sequence of alternating beds of light-gray and white dolomitic limestone, crossbedded light-gray quartzite, and dark-gray dolomitic limestone and argillite in beds ranging from a few inches to 2 feet thick is conspicuous. Wallace argillite in places contains abundant sericite commonly aligned parallel to stratification (Dahlem, 1959).

PIEGAN GROUP—EASTERN PHASE

The Piegan Group is separable into three units traceable through eastern Lincoln, Flathead, and northern Lake Counties. The lower and upper units are designated P_1 and P_3, respectively, and the middle unit is mappable as the Siyeh Formation.

LOWER PIEGAN (P_1 UNIT)

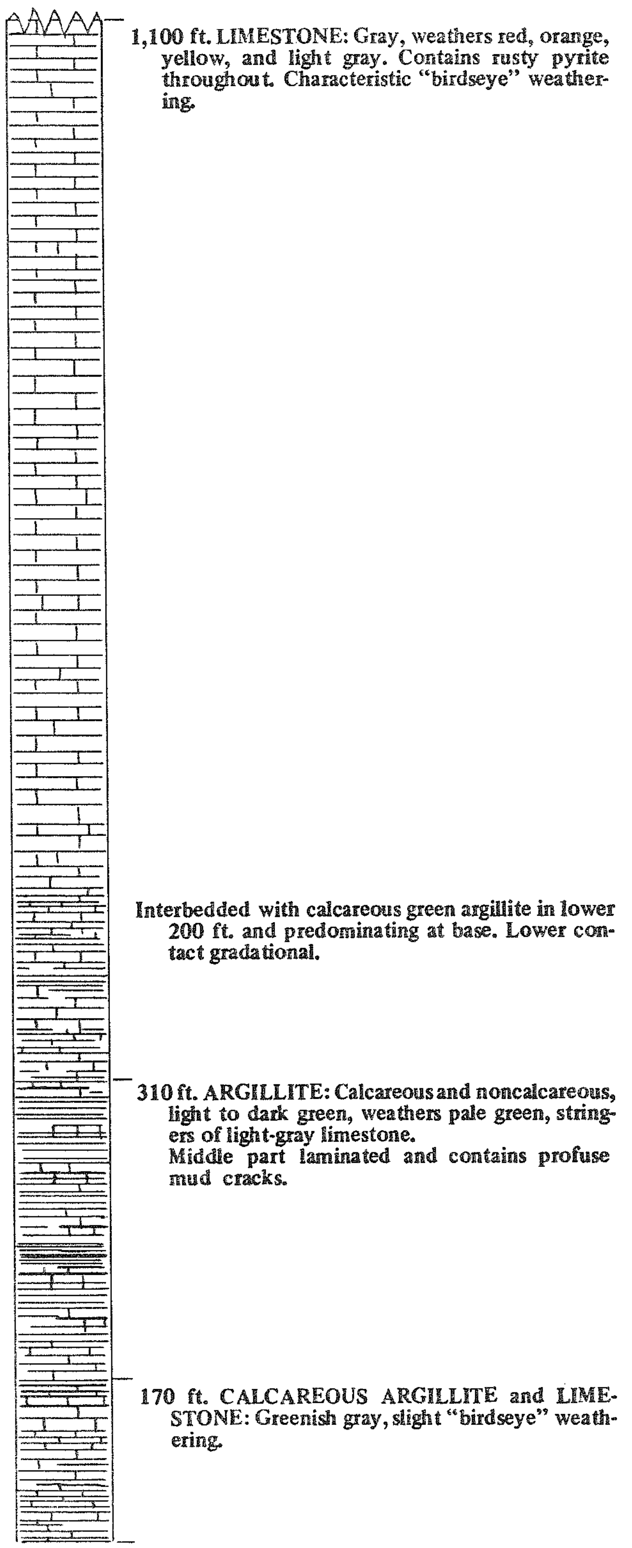
The basal member of the Piegan Group (P_1) was first mapped and described by Shelden (1961) in the Ural area. It is believed to be equivalent to the lower part of the Wallace Formation.

Northwest-trending belts and irregular outcrops of lower Piegan rocks are widespread throughout eastern Lincoln County and Flathead County. In the Whitefish Range, only incomplete sections of the P_1 unit are exposed in a complexly faulted area.

Thickness of the lower Piegan (P_1 unit) ranges from about 1,200 feet to about 3,500 feet. In north-central Lincoln County, Shelden (1961, p. 19) and Sommers (1961, p. 21) reported a thickness of 2,000 feet for the formation. In the Whitefish Range, Smith and Barnes reported a thickness of 1,400 feet.

To the south the lower Piegan unit thickens to 2,700 feet in the Stryker area (Gilmour, 1964, p. 34) and 2,500 to 3,500 feet in the Pleasant Valley area (Johns, 1962, p. 14; Hall, 1962, p. 32). Galster (P_1 section, Fig. 8) measured 2,320 feet of the lower Piegan unit. Near Blacktail Mountain south of Kalispell the thickness was graphically scaled to be about 3,150 feet. Page (Johns, 1964, p 21) reported that the unit is 2,400 feet thick in the Mission Range and thins eastward to about 1,800 feet in the Swan Range. Harrison and others (1969) reported a thickness of 800 feet for the lower unit in the Helena Formation in the central part of the Mission Range. At Badrock Canyon east of Columbia Falls the lower Piegan unit was graphically scaled as about 1,200 feet thick.

Lower Piegan strata are light-greenish-gray and green-gray fine-grained argillite interlaminated with subordinate light-gray coarse-grained argillite, producing a banded appearance. Light-greenish-gray, greenish-white, and greenish-yellow coarse-grained argillite is interbedded with finer grained argillite, but makes up only a minor part of the unit. A few thin gray limestone beds



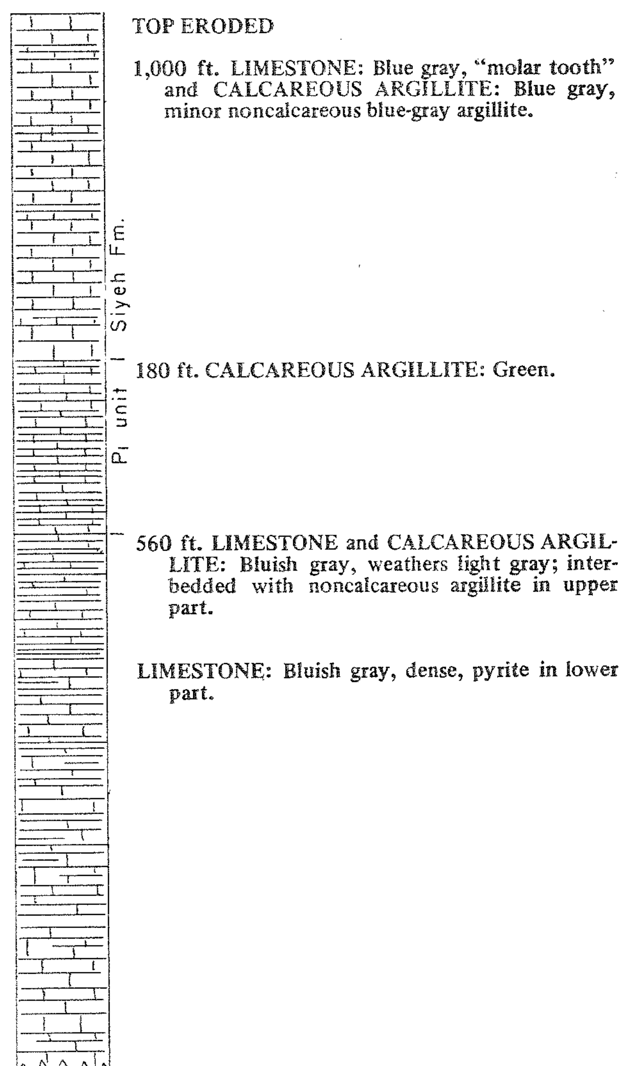


Figure 8.—Lower Piegan (P_1) and part of Siyeh Formation, section on east slope of Elk Mountain, in sec. 2 and 10, T. 31 N., R. 26 W. (After Galster, U. S. Army Corps of Engineers).

throughout and purplish-gray argillite interbedded with greenish-gray argillite in the lower third of the unit are also minor parts. The unit contains mud-chip breccia and is partly calcareous and dolomitic, the carbonate content increasing upward in the section. Leaching of calcareous material produces elongate cavities along bedding planes in the upper part of the section. In unweathered rock, limy oval nodules attain lengths of several inches. Green-gray and light-gray quartzite and quartzitic sandstone are sparse and decrease in abundance toward the top of the unit. Many beds contain casts of mud cracks.

Micaceous minerals, especially sericite and chlorite, are abundant in places, but quartz, feldspar, and biotite make up most of the individually visible rock constituents.

In the Ural area this lower Piegan unit is homogeneous thin-bedded grayish-green argillite that is locally calcareous and in places is somewhat siliceous. Individual quartz grains do not exceed 0.05 mm in diameter. Pyrite and pseudomorphs of limonite after pyrite occur in the unit. Most outcrops weather to pale green (Shelden, 1961, p. 19). Rocks of similar lithology and color were reported by Sommers (1961) in the Rexford-Eureka area.

Near Pleasant Valley the lower Piegan unit consists dominantly of greenish-gray to gray, laminated to thin-bedded argillite and calcareous argillite, much of it silty. The lowermost part contains some purplish-gray calcareous argillite and impure limestone. Near the base of the unit, the strata contain only occasional masses and cubes of pyrite, and the beds weather pale greenish gray, but toward the top, where pyrite is more abundant, the strata weather to pale shades of brown. In thin section the rock is seen to be an argillaceous mat containing abundant sericite and scattered patches of coarser grained calcite and dolomite. Chlorite, in minute flakes, is present in the thin sections in minor amount (Hall, 1962, p. 32).

Similar lithology and color were recorded for the lower Piegan in the Stryker, Kalispell, and Swan Lake areas. The unit is believed to thin abruptly from west to east across the Rocky Mountain Trench in the vicinity of Whitefish and Columbia Falls, and less conspicuously between the southern part of the Salish Mountains and the Swan Range.

The contact of the lower Piegan with the overlying Siyeh is gradational and was placed where greenish-gray calcareous argillite without molar-tooth structure is overlain by dark- and light-gray magnesian limestone displaying molar-tooth structure.

The P_1 unit is correlative with lower Wallace beds in western Flathead County, with the grayish-blue-green calcareous argillite (p€cg) in Glacier Park (Ross, 1959), with the lower unit of the Helena Formation mapped by Harrison and others (1969) in the central part of the Mission Range, and with Smith and Barnes' (1966, p. 1420) Werner Peak Formation of the northern Whitefish Range.

SIYEH FORMATION

The Siyeh Formation was originally named the Siyeh Limestone by Willis (1902, p. 323), and his type section is on Mount Siyeh in Glacier National Park. The name was applied to massive dark-blue or grayish limestone overlying with apparent conformity the Grinnell argillite.

Fenton and Fenton (1937, p. 1892) described the Siyeh Formation as the second dominantly calcareo-magnesian formation in the Glacier Park facies. It includes argillite, quartzite, and extensive mud breccias, as well as thick algal deposits. Dominantly it is dark gray to black; all dolomite weathers buff or fawn. Their type section is also on Mount Siyeh, and they described four subdivisions of the formation.

Ross (1963, p. 70) described the Siyeh Limestone in the Flathead region as equivalent to the lower three subdivisions proposed by the Fentons; he included part of the Fentons' top unit in his transitional p€ca zone (P_3 unit), which he assigned to the Missoula Group. He described the Siyeh as follows:

> "Nearly all the Siyeh Limestone is thick bedded or massive as viewed from a distance, but close examination shows it to be thinly laminated. Some is oolitic. Fresh surfaces are dusky blue, or more rarely greenish gray, with variations related to the composition of the rock. Weathered surfaces show various orange and brownish tones and commonly have irregular etched markings that correspond to differences in calcium carbonate content of the rock . . . The rock consists of carbonate and quartz with some sericite. In most beds individual grains of the major constituents are a few thousandths to a few hundredths of a millimeter in diameter . . ."

In the present report the Siyeh Formation is the equivalent of Ross' Siyeh Limestone in Glacier National Park and to the middle unit of the Helena Formation in the Mission Range as described by Harrison and others (1969).

In the map area the Siyeh Formation is extensively exposed along the northwest-trending eastern border of the Salish Mountains from the International Boundary to Flathead Lake, as faulted northwest-trending belts in the Whitefish

Range, and as north-trending belts in the Mission and Swan Ranges.

Shelden measured the thickness of the Siyeh Formation west of Rexford as 3,200 feet, but in the Stryker area an incomplete section of the Siyeh was measured as 4,800 feet thick, and a minimum of 5,000 feet of Siyeh is exposed in the vicinity of Ashley Lake. Thickness of Siyeh strata in the Whitefish Range measures 2,900 to 3,300 feet; the formation thickens southeastward to at least 5,000 feet and possibly as much as 7,500 feet in the Swan Range east of Swan Lake.

Rocks mapped as the Siyeh Formation are blocky or massive and thin- to thick-bedded dark-gray, bluish-gray, and light-greenish-gray siliceous limestone and dolomite intercalated with gray, green-gray, and yellow-green argillite and gray-white quartzite. The formation weathers light gray, grayish yellow, orange yellow brown, and red brown, the weathered color depending on the dolomite and pyrite content of the bed. Variegated banding makes some outcrops distinct. On the west slope of the Swan Range the Siyeh Formation is predominantly finely crystalline medium- and light-gray limestone and dolomite, locally almost black. Some argillaceous zones are light gray. In the Whitefish and Swan Ranges massive carbonate-bearing beds tend to form vertical cliffs. West of the Rocky Mountain Trench, flat-lying beds tend to be cliff formers.

The formation displays molar-tooth structure, contains cubic pyrite and limonite pseudomorphs after pyrite, and in some areas is oolitic in its upper part. Two thick mappable stromatolitic limestone layers in the Siyeh contain stromatolites of the *Collenia* type and are believed to be continuous throughout the Northwest (Smith, 1964, p. 51).

Molar-tooth structures of possible organic origin are present in the Siyeh Formation of Glacier National Park, the Whitefish Range, and the Ural area, and to some extent in the Wallace Formation of western Lincoln County. Lenticular to oval pits, some aligned parallel to bedding, occur in the upper P_1 unit and in the Siyeh Formation where calcite segregations have been removed by weathering. The enclosing siliceous limestone or argillite, being more resistant to weathering, forms conspicuous ridges on rock outcrops. These ridges, likened to the ridges on elephant teeth, account for the use of term "molar-tooth structure". Hall (1962, p. 35) observed pyrite, in masses and cubes, in nearly all of the calcite masses and suggested that the calcite may have been deposited by lime-secreting algae. If so, decay of the algae could have provided reducing conditions under which the pyrite was formed.

Smith (1968) concluded that molar-tooth structures are complex calcite vein systems deformed by compaction of enclosing sediments before lithification, and that the amount of compaction can be inferred from the amount of deformation of the vertical veins, which are assumed to have been linear at the time of origin. An organic origin is consistent with Smith's observations, but has not been proved.

A quite different structure consists of elliptical calcite nodules resembling pecans and lying parallel to bedding, which were observed in outcrop and in mantle rock east of upper Pinkham Creek. In cross section the nodules display radial septalike partitions suggesting possible organic origin. It was concluded that the calcite nodules were probably calcite segregations of inorganic origin.

Petrographic study of thin sections shows that the typical Siyeh rock contains fine-grained carbonate minerals in an argillaceous matrix. Some fine-grained recrystallized quartz, sericite, and minor chlorite are common, and some hematite may be present.

The contact between the Siyeh Formation and overlying upper Piegan (P_3) was placed where magnesian-bearing limestone beds are overlain by greenish-gray calcareous and noncalcareous argillite of the P_3 unit.

UPPER PIEGAN (P_3 UNIT)

This unit is described as the upper member of the Piegan Group (P_3) in Kootenai-Flathead progress reports. Smith and Barnes (1963) correlated similar rocks in the Whitefish Range with the Snowslip Formation, a name proposed by Childers (1963, p. 144) for a sequence of laminated argillite and quartzite described as dominantly green rocks alternating with equally thick reddish ones. Within the Whitefish Range, Smith and Barnes assigned the Snowslip as the basal member of the upper Belt sequence, but Price (1962) mapped equivalents of the P_3 and of the "Snowslip Formation" of the Whitefish Range as the upper Siyeh, assigning a thickness of 100 feet to the unit. Mapping in Lincoln and Flathead Counties shows the equivalency of the P_3 unit to the upper part of the Wallace. The transitional zone of green calcareous argillite, mapped by Ross (1959) as the basal Missoula unit (p€ca) overlying the Siyeh Limestone and underlying the Purcell Lava, is the equivalent of the upper Piegan unit in the northern part of the Swan Range. In this report the P_3 unit of the Salish Mountains and the Swan and Mission Ranges is treated as the equivalent of upper strata of the Wallace Formation in the Libby area. The Snowslip of Childers is believed to be absent in the Whitefish Range.

The P_3 unit is exposed in the north-central Salish Mountains conformably overlying the Siyeh Formation and underlying the Purcell Lava. The unit occupies the same stratigraphic position in the Whitefish Range. In the north-central Swan Range it is between the Siyeh and Snowslip Formations. Along the west flank of the Rocky Mountain Trench, from a point just south of Eureka to a point beyond Kalispell, P_3 strata have been removed by erosion. Thickness of P_3 strata ranges from 250 feet in the northwest part of the Whitefish Range to about 2,400 feet in the area west and southwest of Rexford. In the northwest part of the Whitefish Range, the unit (P_3) ranges from 250 to 500 feet thick, but it thickens to the southeast and is 2,100 feet thick in the southern part of the Whitefish Range (Smith, 1963, p. 92). In the northeast part of the Whitefish Range the unit is 1,000 to 1,200 feet thick (Barnes, 1963, p. 25). In the north-central Salish Mountains a thickness of 2,400 feet is reported for the formation (Shelden, 1961, p. 25). In Badrock Canyon at the north end of the Swan Range these strata are estimated to be 1,800 to 2,000 feet thick (Johns and others, 1963, p. 27). On the Swan divide east of Swan Lake the P_3 unit is about 1,000 feet thick.

The upper Piegan unit in the north-central Salish Mountains consists of homogeneous thin- and medium-bedded, greenish-gray and light-gray quartzose argillite and quartzite overlain by the Purcell Lava. About 200 feet below the base of the flow, two 8-foot limestone beds are intercalated with the quartzite (Shelden, 1961, p. 25).

On the northeast flank of the Salish Mountains from Rexford to Eureka and continuing southeast, P_3 strata were described by Sommers (1961, p. 21) as light- to medium-dark-greenish-gray thin-bedded noncalcareous argillite lacking molar-tooth structure. He described beds near the Purcell Lava as consisting of dark-greenish-gray argillite in alternating fine dark and light layers. About 500 feet below the base of the lava the sequence contains structures indicating possible channels.

In the northwest part of the Whitefish Range rocks in similar stratigraphic position are greenish-gray and light-green thin-bedded and laminated siltstone and fine-grained quartzite, locally calcareous and dolomitic. Mud cracks, ripple marks, and pyrite cubes as large as 5 mm are sporadically distributed throughout the unit. East of Blue Sky Creek some red siltstone and quartzite are included in the upper part, but throughout the Whitefish Range the P_3 unit is characterized by laminated and thin-bedded strata, green and gray color, its argillitic and quartzose composition and grain size, and its sporadic carbonate content.

In the northeast part of the Whitefish Range, Barnes (1963, p. 25) described the lithology as fine-grained argillite of various pale tints of green interlaminated with coarse-grained argillite of pale tints of gray and green. Very fine grained quartzite forms rare discontinuous cross-laminated lenses. Most of the argillite is calcareous, especially the coarser layers, and cementation may be nearly contemporaneous with clastic deposition, as a few fragments of calcareous fine- to medium-grained sandstone were found imbedded in coarse, cross-laminated argillite. Some of the argillite is feldspathic, but most contains only minor feldspar. Muscovite and chlorite make up as much as 25 percent of the rock. Near the top, the unit contains more dusky-red and grayish-red coarse- to fine-grained argillite than greenish-gray argillite; therefore, where the lavas are absent, it may be difficult to place the upper contact. It may be arbitrarily placed where the argillite grades upward into the yellow-brown-weathering dolomitic rocks of the Shepard Formation.

The P_3 unit in the north-central part of the Swan Range overlies the Siyeh Formation and underlies the Snowslip. The formation consists of pale-green and grayish-green thin-bedded and laminated argillite, calcareous argillite, and impure limestone. Mud cracks and mud breccia are moderately abundant. These rocks weather grayish orange and yellow brown. Locally, weathering has produced solution holes, which give the surface outcrop a pocky appearance.

The Wallace Formation of western Lincoln County and of areas farther south and west is believed to be equivalent to the three units of the Piegan Group in eastern Lincoln County and Flathead County; to the Helena Formation of the Mission Mountains in Missoula County; to the p€cg, Siyeh, and p€ca units (Ross, 1959) in the Flathead region and Glacier National Park; and the Kitchener-Siyeh Formation of southeastern British Columbia. The Piegan Group is correlated with the Siyeh Formation in the Marias Pass area, as the term "Siyeh" was used by Childers (1963).

The gross lithology and sedimentary features of the Piegan Group, and to a lesser extent the Wallace Formation, suggest a complete cycle of sedimentation commencing with deposition of fine-grained calcareous argillite (P_1), deposition of carbonate-bearing strata (Siyeh), and a return to deposition of fine-grained calcareous and siliceous argillite (P_3).

MISSOULA GROUP—WESTERN PHASE

The name Missoula Group was first used by Clapp and Deiss (1931, p. 677) for a sequence of argillite and quartzite 18,000 feet thick overlying the Wallace Limestone in the Missoula-Helena region. As originally defined the group included all Belt rocks above the Wallace Formation.

In western Lincoln County (western phase of Missoula Group) the Striped Peak and Libby Formations make up the Missoula Group. In northeastern Lincoln County and northern Flathead County all units from the Purcell Lava upward are included in the north-central phase of the Missoula Group. In southeastern Flathead County, where the Purcell Lava is absent, the basal Missoula unit is the Snowslip Formation, and the upper Missoula unit underlying Middle Cambrian rocks is the McNamara Formation.

STRIPED PEAK FORMATION

The Striped Peak Formation was named by Calkins (Ransome and Calkins, 1908, p. 25) for a mountain of that name in the Coeur d'Alene region in Shoshone County, Idaho. Striped Peak beds in the Coeur d'Alene region are composed of ripple-marked and mud-cracked red, purple, and green shale and quartzitic sandstone. Gibson and others traced the formation from the Coeur d'Alene region to the Libby quadrangle in southwestern Lincoln County where its thickness ranges between 2,000 and 2,500 feet. The formation there is described (Gibson, 1948, p. 16) as thin-bedded ferruginous and sericitic dark-red to purplish sandstone and quartzite locally containing some stromatolitic dolomite associated with oolitic dolomite and sandy dolomitic limestone. Gibson reported crossbedding, ripple marks, and sun cracks as being common throughout the formation.

In the western part of Lincoln County, Striped Peak beds are exposed on both limbs of a syncline that crosses the Kootenai River between Libby and Troy. Outcrops of Striped Peak strata continue north, and in the Quartz Creek-China Mountain area north of Kootenai Falls they merge around the nose of the syncline. Striped Peak strata are also exposed along Vermilion River in northern Sanders County and northwestward across Fisher River (Thompson Lakes area) but they disappear beneath glacial gravel and silt deposited in the valleys of Swamp Creek and Libby Creek. A faulted segment of Striped Peak rocks extends across the lower reach of Wolf Creek to a point near the mouth of Fisher River.

Thickness of the Striped Peak Formation ranges from 2,000 to 2,500 feet in the Libby area and was graphically scaled to be 2,100 feet near Willow Creek, a tributary of Vermilion River, in northern Sanders County. A thickness of 3,000 feet or more was graphically scaled for a complete section of the formation across Squaw Creek.

Striped Peak rocks in the map area are distinctive red and gray quartzite, indurated sandstone, quartzitic argillite, and shaly argillite. Beds are sericitic and ferruginous. Ripple marks, mud cracks, and crossbedding are well developed throughout the formation. The quartzose rocks are medium to coarse grained. The formation is easily recognizable because of its distinctive red color and the striking surface luster produced by light reflecting from sericite flakes on bedding planes. In the Fisher River-Thompson Lakes area the lower part of the Striped Peak is almost all quartzite, but to the north the beds gradually change to argillite and shaly argillite interbedded with only minor quartzite. Near the head of Vermilion River the Striped Peak Formation is reddish quartzite and argillite and gray silty and quartzose argillite. Interbeds of red and grayish-green laminated quartzitic argillite are common near the center of the unit. Near Willow Creek on Vermilion River several thin stromatolitic limestone beds crop out near the base of the unit. Salt-crystal casts were observed at this locality in the argillitic beds a few hundred feet above the base.

The contact between the Striped Peak and Libby Formations is gradational and was placed where predominantly red and gray quartzite and argillite are overlain by predominantly laminated grayish-green quartzitic argillite or gray, green, brown, and yellow ferruginous and locally slightly calcareous sandy argillite of the Libby Formation.

Striped Peak rocks of western Lincoln County and the Pend Oreille region are tentatively regarded as equivalent to the Spruce Formation and Lupine Quartzite of the St. Regis-Superior area and are believed to be correlative with the Shepard, Kintla, and Phillips Formations of the Whitefish Range. The Phillips Formation has been correlated (Smith, 1963, p. 108) with the Red Plume Quartzite of the Marias Pass area.

LIBBY FORMATION

Gibson (1948, p. 17) applied the name Libby Formation to a sequence of light- to dark-gray argillite cropping out in the vicinity of Libby. A typical section of the formation is exposed southeast of Flagstaff Mountain south of the Kootenai River near Libby, where dark- to light-gray and olive-green argillite, sericitic argillite, calcareous argillite, sandstone, and minor amounts of shale and magnesian limestone totaling 2,250 feet in thickness are exposed. The Libby is the uppermost formation of the Belt Series in southwestern Lincoln County, and the top has been removed by erosion.

The Libby Formation, which overlies the Striped Peak Formation, is likewise exposed in the trough of the syncline that crosses the Kootenai River west of Libby, and the outcrop extends north into the Quartz Creek-China Mountain area northwest of Libby. A belt of Libby rocks extending northwestward from the upper reaches of the Vermilion River in northern Sanders County disappears beneath valley fill in Swamp Creek and Lake Creek valleys.

Gibson (1948, p. 18) reported at least 6,000 feet of Libby rocks exposed in the syncline crossing the Kootenai River west of Libby. In the Thompson Lakes region the thickness was graphically scaled as 7,600 feet. Within the syncline at the head of Vermilion River the exposed part of the Libby is about 5,000 feet thick. In the Pend Oreille area, where the Libby is about 1,800 feet thick, Harrison and Jobin (1963) divided it into three members.

In the type area, the most common rocks in the Libby Formation are dark- and light-gray and greenish-gray argillite in beds 1 to 3 feet thick. The rocks are somewhat sandy, sericitic, and calcareous, and some dark-gray ferruginous and oolitic magnesian limestone is locally present. Farther southeast, in the area west of Thompson Lakes, yellowish tints appear, and some yellow-brown and grayish-yellow impure limestone is interlayered in the sequence. At the headwaters of the East Fisher River near Miller Lake, Libby rocks exposed on the east limb of a north-plunging syncline consist of dark- to light-green, gray-black, yellowish-brown, grayish-brown, and yellowish-gray argillite. Some strata contain profuse rodlike to irregular molds or casts of concretions(?) on bedding planes.

The Libby Formation of southwestern Lincoln County and the Pend Oreille area is believed to be correlative with most of the Roosville Formation of the Whitefish Range, and it has been previously correlated with the Bouchard Formation of the St. Regis-Superior area, which in turn is believed to correlate with the Garnet Range Formation of Nelson and Dobell (1961). The Sloway is described as having no stratigraphic equivalent in the Libby, Pend Oreille, and Trout Creek areas; its absence is attributed to nondeposition or to removel by erosion (Harrison and Campbell, 1963).

MISSOULA GROUP—NORTH-CENTRAL PHASE

PURCELL LAVA

The Purcell Lava was recognized by Willis (1902), Daly (1905), and others as a marker unit as early as the beginning of the century. It was named the Purcell Lava by Daly (1912, p. 207). Clapp (1932) identified the flow as basalt. In northern Lincoln and Flathead Counties the lava extends eastward from long 115° 31' W. to Glacier National Park; it does not extend south beyond the Whitefish Range or the central part of Glacier Park. Where exposed northwest of Rexford it consists of two distinct groups of flows separated by as much as 100 feet of gray and green quartzitic argillite (Johns, 1962b, p. 190). In parts of British Columbia the value of the Purcell Lava as a marker is questionable because of possible confusion with any of several other flows higher in the sequence.

Near long 115° 31' and just south of the Canadian boundary Purcell Lava crops out in a broad U-shaped pattern; several fingers extend southward in the vicinity of Robinson Mountain. From Rexford to Eureka and beyond, faulted Purcell Lava crops out in an arc, the lava overlying P_3 strata and underlying the Shepard Formation. Within the Whitefish Range, the lava is thickest in the north-central part, thinning southeastward and disappearing near the junction of Canyon and Kimmerly Creeks (lat 48° 30' 30").

Sheldon (1961, p. 46) described the Purcell Lava northwest of Rexford as comprising a lower flow of basic rock 450 feet thick and an upper flow of acidic rock not exceeding 100 feet thick, separated by thin-bedded greenish-gray argillite and quartzite 75 feet thick.

Between Rexford and Eureka the Purcell Lava (Sommers, 1961, p. 24) is 700 feet thick and consists of two flow units separated by a 1-foot zone of argillite. On the Burma road northeast of Eureka, an agglomerate of Purcell pebbles overlies the basalt flow.

In the northern part of the Whitefish Range a thickness of 450 feet is reported for the lavas on Mount Ksanka and Green Mountain, 300 feet on Poorman Mountain, and 390 feet on Bluesky Ridge (Smith, 1963, p. 95). South of Yakinikak Creek, Barnes (1963, p. 28) reported a thickness of 400 to 500 feet and he found no evidence of disconformity at the base of the flow. In most places the underlying argillite (Piegan P_3 unit) is altered to a depth of 6 inches or less, but Sommers (1961, p. 24) described a 10-inch baked zone of laminated greenish-gray argillite that seems to have been crumpled by the lava, attesting to the unconsolidated nature of the sediment at the time of extrusion. The flow thins southeastward and is only 20 feet thick on Standard Peak in the southern part of the Whitefish Range.

Purcell Lava was extruded just before the termination of deposition of the Wallace Formation and Piegan Group, and in part of northwest Montana it is a marker separating the underlying P_3 and overlying Shepard Formations. It is classed as the basal unit of the Missoula Group in northern Lincoln and Flathead Counties, but where the flow is absent, the base of the Missoula Group is mapped at the base of the Striped Peak and Snowslip Formations of this report, or other, correlative formations. If the unit had extended southwest into the Libby region, the position of the flow might have been slightly below the Wallace-Striped Peak contact.

Shelden (1961, p. 46) described the lower flow as threefold—a lower pale-green lava breccia zone in which the lava contains angular fragments of sedimentary rock, a middle zone of grayish-green porphyritic nonamygdaloidal lava, and an upper zone of greenish-black aphanitic amygdaloidal lava. The upper zone contains amygdules grading from vertical pipes through round amygdules into elongate horizontal amygdules, the gradation suggesting surface flowage. The lower Purcell lavas were described by Daly (1912, p. 207) as exhibiting a diabasic texture.

A grayish-green porphyritic lava containing quartz and plagioclase phenocrysts is exposed at the base of the upper flow. Shelden (1961, p. 52) identified these rocks as rhyolite or quartz latite. Overlying the acid igneous rocks is grayish-green basalt containing vesicles filled with secondary quartz and calcite.

Within the Whitefish Range the flow was described (Smith, 1963, p. 95) as bluish gray and grayish purple on fresh surfaces, weathering to brownish olive gray. Pillows are present in the basalt flow, and overlying flows have "ropy" upper surfaces indicative of subaerial eruption.

SHEPARD FORMATION

Willis (1902, p. 324) applied the name Shepard Quartzite to ferruginous quartzite overlying Purcell Lava between Belly River and Flattop Mountain in northern Glacier National Park. A decision of the Committee on Geologic Names (Wilmarth, 1938, p. 1980) approved the name Shepard Formation for the sequence consisting of quartzite and sandstone, dolomitic quartzite, dolomite, and argillite overlying Purcell Lava and underlying the Kintla Formation.

Shepard rocks composed of feldspathic sandstone, dolomite, and argillite are exposed around the northwest end of the Salish Mountains in an arcuate pattern extending from Rexford to a point southeast of Eureka and also crop out in the Purcell Mountains northwest of Rexford. The formation crops out farther east in the Whitefish Range, where it consists of quartzite, dolomite, dolomitic argillite, and siltstone.

Thickness of the Shepard Formation in the northern part of the Whitefish Range is 183 to 350 feet in the west (Smith, 1963, p. 99) and increases to 400 to 500 feet in the east (Barnes, 1963, p. 30). About 400 feet of Shepard crops out in the southern part of the Whitefish Range. Sommers (1961, p. 26) reported 800 feet or more of the formation at the northern end of the Salish Mountains, and correlated it with the lower part of the Gateway (Daly, 1912). In the Purcell Mountains northwest of Rexford, Shelden (1961) mapped 600 feet of Shepard strata overlying Purcell Lava.

The Shepard Formation in the Purcell Mountains northwest of Rexford is described as consisting of three kinds of rock—a basal pale-green sandstone 150 feet thick exhibiting prominent graded bedding and resembling a reworked graywacke, overlain by silty dolomite containing laminae of argillite, which in turn grades upward into magnetite-bearing greenish-gray quartzitic argillite. Pyrite cubes and salt casts were observed in this sequence, and annelid trails(?) were noted in the upper argillite (Shelden, 1961, p. 26).

Farther south, at the north end of the Salish Mountains, the lower part of the Shepard is dark-greenish-gray and light-gray thin-bedded argillite, which grades upward into green-gray feldspathic sandstone exhibiting graded bedding and crossbedding. The central part of the Shepard contains medium- and light-gray dolomite and stromatolitic dolomite. Upper beds in the Shepard consist of fissile green-gray quartzitic argillite interlayered with thin-bedded dolomite. An agglomerate at the base of the Shepard Formation, which contains rounded pebbles of Purcell Lava, is exposed near the Burma road northeast of Eureka (Sommers, 1961).

In the northern part of the Whitefish Range, Shepard rocks include well-sorted light-gray dolomitic quartzite and pebbly sandstone, purplish-gray poorly sorted quartzite, and greenish-gray and gray dolomite and dolomitic argillite, which weather yellowish orange. In the southern part of the Whitefish Range, the Shepard Formation contains interbedded medium- to light-gray crossbedded calcareous and dolomitic quartzite, gray oolitic limestone, and pale-orange stromatolitic dolomite, which weather grayish orange or yellowish orange. Some grayish-green and gray dolomitic argillite and siltstone are interbedded, the argillite and siltstone content increasing southeastward at the expense of the quartzite and stromatolitic dolomite.

The contact is transitional from light-greenish-gray or light-gray dolomitic argillite and dolomitic quartzite of the Shepard to green-gray and gray-red-purple argillite of the overlying Kintla.

On the basis of stratigraphic position and lithologic features, the Shepard Formation is correlated with the lower part of the Gateway in the Ural area and southeastern British Columbia. It has also been correlated with uppermost Wallace beds and the lower part of the Dutch Creek Formation (Smith and Barnes, 1966, p. 1421).

KINTLA FORMATION

Willis (1902, p. 324) applied the name Kintla Argillite to an 800-foot sequence of red argillite near Upper Kintla Lake in the northwest corner of Glacier Park. The formation crops out throughout the Whitefish Range, between the Shepard and the Phillips, and commonly contains salt casts, mud cracks, and ripple marks. The rocks are gray, green, grayish red, or purple; the lower and upper parts contain rare stromatolitic dolomite.

Basal beds of the Kintla Formation, about 1,000 feet thick, are exposed along the Great Northern Railway 5 miles northeast of Rexford. Kintla rocks are in fault contact with Devonian strata about 1 mile southeast of Roosville, a port of entry at the International Boundary north of Eureka. Throughout the Whitefish Range the thickness of the Kintla Formation ranges from 2,900 to 3,300 feet.

Beds in the lower part of the Kintla consists of greenish-gray coarse-grained micaceous argillite or fine-grained poorly sorted feldspathic sandstone and quartzite containing parallel and cross laminations, and interlaminated grayish-red-purple fine-grained argillite. Rocks in the upper part of the Kintla consist of greenish-gray coarse-grained and partly cross-laminated argillite interlaminated with pale-red to yellowish-gray or brownish-gray fine-grained argillite.

Thin beds of gray silty dolomite in the uppermost part of the Kintla weather grayish yellow orange. Thin stromatolite dolomite zones are interlayered with quartzite locally in the lower part of the formation. Kintla rocks exhibit flaggy weathering and produce extensive talus slopes. Salt-crystal casts and molds distinguish this formation from similar rocks in other formations, particularly the Snowslip.

Current ripple marks, mud cracks, crossbedding, and mud-chip breccia, though common in the formation, are not ubiquitous.

The boundary between the Kintla and Phillips Formations is gradational and occurs in a transitional zone from predominantly green to gray thin- to medium-bedded Kintla quartzite containing salt casts to predominantly grayish-red medium-grained quartzite without salt casts.

Kintla rocks of northeastern Lincoln County are believed to be correlative with part of the Striped Peak of the Libby area, to the upper part of the Gateway in southern British Columbia and Alberta, to part of the "main body" (Ross, 1959), to the Hoadley Formation (Deiss, 1947), but only to the upper part of the Hoadley as that term was used by Mudge (1966). The Kintla is correlated with the Shields Formation in the Lewis and Clark and Mission Ranges and with the upper beds of the Miller Peak of the Missoula area.

PHILLIPS FORMATION

The name Phillips Formation was applied by Daly (1912, p. 108) to a sequence of grayish-red argillitic and quartzitic rocks exposed near Phillips Creek several miles northeast of Roosville, in the southern part of the Galton Range, British Columbia.

The Phillips Formation is exposed in the Whitefish Range (Pl. 2), but the name has not been applied to equivalent rocks in the rest of the area. Thickness of the formation ranges from 400 feet at the head of Seemo Creek to 750 feet on Mt. Hefty (Barnes, 1963, p. 39) in the northeast part of the Whitefish Range. In the southern part of the range the thickness is almost uniformally 650 to 700 feet.

The Phillips Formation consists of moderate-grayish-red to moderate-dusky-red, very fine grained to fine-grained feldspathic sandstone and quartzite containing interlayered grayish-red and dusky-red coarse-grained argillite and lesser amounts of grayish-pink and pale-red sandstone. Locally, moderate-red mud chips are common. In some areas light-greenish-gray sandstone occurs in the lower few feet of the formation. Particularly in this basal section, medium to coarse rounded and frosted sand grains of probable eolian origin are locally present along lamination planes. Argillite layers contain ripple marks and mud-crack casts; the quartzite and sandstone are crossbedded.

The contact between the Phillips and Roosville Formations is gradational over about 100 feet. Rocks near the top of the Phillips, consisting of grayish-red and dusky-red argillite and pink quartzite, are interlayered with green laminated argillite and siltstone of the Roosville Formation.

The Phillips Formation of the Whitefish Range has been correlated with part of the Striped Peak of the Libby area. Smith (1963) correlated it with the Red Plume Quartzite of the Marias Pass area, which is in turn equated to the lower part of the Ahorn Sandstone on the basis of lithologic features and stratigraphic position. Mudge (1966) equated the lower member of the Ahorn Sandstone with the Bonner Formation.

ROOSVILLE FORMATION

Greenish-gray argillite cropping out in the southern part of the Galton Range northeast of the Roosville port of entry on the International Boundary was named the Roosville Formation (Daly, 1912, p. 109). In the Whitefish Range it includes all strata between the Phillips quartzite below and Cambrian quartzite and shale above (Barnes, 1963).

Outcrops of Roosville rocks (Pl. 2) are adjacent to those of the Phillips Formation. Graphically scaled thicknesses range from 4,500 feet at Review Mountain to about 6,000 feet in the northwest part of the Whitefish Range. In the southern part of the range, the upper beds of the Roosville are faulted out, but the remaining part is at least 4,000 feet thick along Dead Horse Creek.

The lower part of the formation consists of laminated greenish-gray coarse-grained argillite interlayered with light-greenish-gray fine-grained argillite most of which is noncalcareous. The coarser laminae contain mud chips of greenish-gray, reddish-brown, grayish-orange, and yellowish-orange fine-grained argillite. A 35-foot zone of red and red-purple coarse-grained argillite containing thin laminae of red fine-grained argillite occurs about 700 feet above the base. Some light-gray, medium-light-gray, and greenish-gray quartzite is also interlayed in the lower part of the formation. Within the lower 1,000 feet, dolomitic stromatolites of the *Collenia* type are present. The middle part consists of pale-red quartzite interbedded with greenish-gray argillite overlain by olive-gray argillite and light-gray quartzite. The upper 500 feet or more of the formation is composed of interbedded dark-greenish-gray fine-grained sericitic quartzite and greenish-gray or dark-gray argillite or sandy siltstone. Some purple-gray quartzite occurs at the top of the formation in the northwest part of the Whitefish Range.

Uppermost Roosville beds of dark-gray micaceous argillite and siltstone are overlain by the Flathead Formation (Middle Cambrian). Barnes (1963, p. 26) observed Flathead resting uncomformably on Roosville but from only small exposures he was unable to detect angular discordance.

The Roosville Formation of the Whitefish Range has been correlated with the upper member of the Ahorn Sandstone, and that, in turn, with the McNamara Formation (Mudge, 1966). At least part of the Roosville of the Whitefish Range is believed to be correlative with the Libby Formation farther west and with the "unnamed sequence" (Childers, 1963) of the Marias Pass area.

MISSOULA GROUP—EASTERN PHASE

Clapp and Deiss (1931, p. 677) named a thick group of fine clastic rocks the Missoula Group from exposures east of the city of Missoula. In this area the group was divided into five units, later redefined by Nelson and Dobell (1961), which in ascending order are the Miller Peak Argillite, Bonner Quartzite, McNamara Argillite, Garnet Range Quartzite, and Pilcher Quartzite; thickness totals 14,300 feet. Farther northeast, in the Saypo quadrangle, Deiss (1943a, p. 215) divided the 8,200 feet of strata in the Missoula Group into four formations, which from the base upward are Miller Peak Argillite, Cayuse Limestone, Hoadley Formation, and Ahorn Quartzite. He traced the Miller Peak Argillite from its type section on Miller Peak to the central part of the Lewis and Clark Range. In the same area, however, Mudge (1966b) has mapped four siltstone and sandstone members and has assigned them to an expanded Hoadley Formation approximately equivalent to Miller Peak, Cayuse, and Hoadley as used by Deiss. Mudge also divided the Ahorn into a lower and an upper member. The total thickness of the Hoadley and Ahorn units mapped by Mudge amounts to about 4,700 feet. The Missoula Group in the southern part of the Lewis and Clark Range (McGill and Sommers, 1967) in ascending order above the Helena Formation includes the Snowslip, Shepard, Shields, Bonner, McNamara, and Garnet Range Formations. Mudge (personal communication) regards these units as well defined, and he intends to use the same nomenclature in his future reports. In the Marias Pass area south of Glacier Park, Childers (1963) divided the formations above the Siyeh in ascending order into the Shepard, Shields, Red Plume, and an overlying "unnamed sequence" totaling about 7,000 feet in thickness.

In the Swan Range a thick body of predominantly clastic maroon sedimentary rocks is assigned to the Missoula Group, which is here subdivided into five units, in ascending order the Snowslip, Shepard, Shields, Bonner, and McNamara Formations (Pl. 3). The contact with the underlying Piegan Group is placed at the top of the P_3 unit and the base of the Snowslip Formation. Total thickness of the Missoula Group in the central Swan Range amounts to at least 12,000 feet and may be as much as 14,500 feet.

SNOWSLIP FORMATION

Childers (1963) proposed the name Snowslip Formation in the Marias Pass area for a sequence of alternating red and green thin- to thick-bedded argillite, quartzite, and sandstone beds overlying the Siyeh and underlying the Shepard Formation. In the Silvertip region, Deiss described red argillite and subordinate grayish-green interbedded argillite overlying the Helena Formation as the Miller Peak equivalent, the sequence being traceable (according to Deiss) from the Missoula area to the Silvertip quadrangle. As the term is used in this report, the Snowslip consists of red argillite, siltstone, and quartzite and subordinate gray-green argillite. It overlies the P_3 unit of the Piegan Group and underlies the Shepard Formation. It is the basal unit of the Missoula Group in southeastern Flathead County.

Snowslip strata were mapped in the Swan Range east of long 113° 45' paralleling the Swan Divide from Bunker Creek southeast to Little Salmon Creek (Pl. 3). Between Bruce Mountain and Crevice Lake the Snowslip is about 1,700 feet thick; it thickens toward the southeast, and was graphically scaled to be 2,000 feet thick near the south end of the mapped outcrop.

Red argillite, siltstone, and quartzite predominate throughout the Snowslip; green and gray-green argillite and siltstone make up less than one-third of the unit. At the base is grayish-red and pale-red argillite, sandy argillite, and sandstone, interlayered with a few beds of light-gray quartzite. Next is a thin sequence of laminated pale- and grayish-green argillite and siltstone; some layers contain a small amount of carbonate. Overlying the grayish-green part is dusky-red and gray-red argillite, in which are intercalated a few beds of pale-pink and grayish-green argillite and quartzite. Above that reddish sequence, thin green and gray-green rocks are intercalated in grayish-red and dusky-red argillite, siltstone, and quartzite. Mud cracks, ripple marks, and mud breccia occur throughout the Snowslip strata.

A comparatively narrow transitional zone separates the pale-green and gray-green calcareous argillite of the underlying P_3 unit of the Piegan Group from ripple-marked grayish-red argillite of the lower part of the Snowslip Formation. The upper contact of the Snowslip was placed where grayish-red and pale-red ripple-marked argillite and quartzite are overlain by yellow-weathering gray calcareous argillite and limestone (Shepard Formation).

The Snowslip Formation in the Swan Range and the Marias Pass area is correlated with Miller Peak Argillite (Deiss, 1943a) farther south. In the Sawtooth Range, the red and tan siltstone member (basal unit of the Hoadley Formation) is correlative with the Snowslip (Mudge, 1966b).

The Snowslip Formation seemingly is not traceable from the Swan Range to the Whitefish Range, where Purcell Lava separates the P_3 unit of the Piegan Group from the Shepard Formation. Mudge (personal communication) could not trace Miller Peak strata to the Pretty Prairie quadrangle, and he is of the opinion that Miller Peak strata are absent there.

SHEPARD FORMATION

The Shepard Formation, stratigraphically overlying the Snowslip, is a dominantly carbonate rock sequence similar in composition and color to the Siyeh Formation. Thickness is helpful in distinguishing between the two formations, the Shepard being much thinner than the Siyeh.

Shepard rocks occupy a median position within the lower half of the Missoula Group. The formation is exposed continuously along the east flank of the Swan Range from Kah Mountain south to Oreamnos Peak. Graphically scaled thicknesses for the formation range from 800 feet on Bruce Mountain to 1,200 feet at a point north of Little Salmon Creek, the average being approximately 1,000 feet.

The Shepard consists of about 1,000 feet of limestone and subordinate clastic rocks. The carbonate beds include finely crystalline medium- and light-gray limestone, pale-green and gray-green limestone, and argillaceous limestone that weathers yellow brown, medium gray, and light gray. The interbedded clastic rocks are minor beds of gray argillite and calcareous argillite. A few beds of gray and grayish-red quartzite are present, as are a few 3-inch stromatolite beds. Weathering and solution produce structures that simulate molar-tooth structure locally in the carbonate rocks. An indented or pocky yellow-brown weathered surface is characteristic of the limestone in the Shepard. The contact between the Shepard and overlying Shields Formation was placed where yellow-brown-weathered gray limestone (and calcareous argillite) is sharply transitional into light-gray and pale-red argillite and interlayered quartzite.

The Shepard Formation in the Whitefish and Swan Ranges and the Salish Mountains is correlative with the Cayuse Limestone in the Lewis and Clark Range (Deiss, 1943a). Mudge (1966b) correlated a tan siltstone member of the Hoadley Formation in the Pretty Prairie quadrangle with the Shepard Formation of the Marias Pass area.

SHIELDS FORMATION

The name Shields Formation was proposed by Childers (1963) for a stratigraphic unit that crops out between Mount Shields and Blacktail Mountain in the Marias Pass area. The unit also crops out along the eastern flank of the Swan Range. Faulting and folding repeat parts of the section, but a minimum thickness of 3,000 feet is believed reasonable.

Red clastic rocks make up the largest part of the Shields Formation in the Swan and Lewis and Clark Ranges. The unit consists of thin- to medium-bedded grayish-red, pale-red, and gray argillite, siltstone, quartzite, and feldspathic sandstone, thin- and medium-bedded pinkish-red quartzite and sandstone, minor amounts of light-gray calcareous siltstone and greenish-gray fissile siltstone, and occasional beds of light-gray carbonate rocks that weathers yellow to grayish orange and yellow brown. Mud cracks and ripple marks are fairly abundant throughout the formation, and occasional crossbedding was observed in quartzite and sandstone. Sericite is common along bedding planes in the clastic rocks. The contact is tentatively placed where thin-bedded sericitic ripple-marked grayish-red siltstone and argillite of the Shields Formation grades into grayish-red and pink quartzite of the Bonner Formation. In the Marias Pass area the Shields Formation consists of red and maroon siltstone, sandstone, quartzite, and shale.

The Shields Formation is correlated with the upper two (red sandstone and red siltstone) members of the Hoadley Formation farther south and with the Kintla Formation in the Whitefish Range.

BONNER FORMATION

Nelson and Dobell (1961) applied the name Bonner Quartzite to a sequence of clastic rocks well exposed in the vicinity of Bonner, east of Missoula. Within the Bonner quadrangle this sequence is described as the most easily identified formation in the Missoula Group.

Lower and middle Bonner strata are poorly exposed in the map area (Pl. 3) where they are extensively covered by Quaternary glacial deposits and alluvium in the valley of the South Fork Flathead River. Upper Bonner strata are intermittently exposed along the east side of the valley of the South Fork from the mouth of Twin Creek to Spotted Bear Ranger Station. A graphically scaled thickness amounts to about 1,850 feet, but the position of the lower contact (Shields-Bonner contact zone) is inferred, and errors in thickness could be introduced both by misplacement of the contact and by faulting concealed beneath Quaternary deposits.

The Bonner Formation in southeast Flathead County consists of pale-red, light-red, and grayish-red to grayish-pink thin- to thick-bedded quartzite and sandstone, containing near the base and top of the unit sparse interbedded pale-green sericitic siltstone.

The contact with the overlying McNamara Formation was placed where grayish-red and grayish-pink to pink thin- and medium-bedded quartzite is transitional to mud-cracked pale-green siltstone and sandstone that weather gray green.

In the Bonner quadrangle the formation consists of pink and pale-red to grayish-red vitreous quartzite and minor interbedded argillite. The quartzite is predominantly arkosic and much of it is crossbedded.

Bonner rocks in the map area are correlated with the lower member of the Ahorn Sandstone, with the Red Plume Quartzite, and, in the Whitefish Mountains, with the Phillips Formation.

McNAMARA FORMATION

Clapp and Deiss (1931) applied the name McNamara Formation to a thick group of rocks exposed east of Bonner in the vicinity of McNamaras Landing.

McNamara rocks are exposed underlying Flathead Sandstone (Cambrian) in a belt trending southeast from lower Twin Creek to Spotted Bear River and beyond. The formation was graphically scaled to be 2,200 feet thick, but there is some evidence that bedding-plane faults may repeat or cut out part of the section.

McNamara rocks are exposed along the lower reach of Spotted Bear River, below Horse Ridge, and along the lower part of Twin Creek in the Flathead Range. The lower beds predominantly consist of green-gray-weathering thin-bedded pale-green and greenish-gray sandy argillite and siltstone, locally somewhat calcareous, interbedded with sparse grayish-red argillite and siltstone, followed in ascending order by light-blue-gray and green-gray thin-bedded and fissile sandy argillite, siltstone, and quartzite, weathering yellow gray, followed by light-gray-weathering thin-bedded fine- to medium-grained grayish-red quartzite that underlies Flathead Sandstone (Cambrian).

In the Lewis and Clark Range west of Pagoda Mountain, upper McNamara(?) beds underlie Flathead Sandstone and consist of medium-light-gray, pale-green, and greenish-gray sandstone, quartzite, argillaceous quartzite, or argillite several hundred feet thick. The green- and gray-weathering sandstone beds are feldspathic.

Deiss (1931) described the McNamara as consisting of a lower greenish-gray to purple and maroon sandy argillite, a middle member composed of grayish-green sandy quartzite and pinkish-white and reddish-gray crossbedded quartzite, and an upper member described as bright-green and red fine-grained argillite.

The McNamara Formation is correlated with the upper member of the Ahorn Sandstone, with the "unnamed sequence" in the Marias Pass area, and with the Roosville Formation of the Whitefish region.

MAIN BODY (ROSS)

The main body, as the term was used by Ross (1959), includes the greater part of the Missoula Group and consists of an assemblage of grayish-red, purplish-red, brownish-red, and grayish-green rocks that crop out over a large area in the Flathead region. Rocks include quartzite, argillaceous quartzite, argillite, and calcium and magnesium carbonates. Discontinuous limestone lenses within the main body were described, but because the Siyeh Limestone was mistaken for Missoula strata along the Middle Fork Flathead River (Childers, 1963, p. 150) the occurrence and discontinuous extent of these carbonate-bearing strata within the main body is subject to some question. Magnesian carbonate strata of the Shepard Formation are included within the lower part of Ross' main body (Pl. 3), but to the north in Glacier National Park the Shepard was mapped separately. Pink quartzite (p€q) at the top of the main body is shown separately on Plate 3 wherever Ross identified the unit.

Oscillation and cusped ripple marks and mudcracked surfaces are common in the argillite beds of the Missoula Group. Intraformational conglomerate is also present.

Ross (1959, p. 50) estimated that in the Flathead region the thickness of the Missoula Group is at least 10,000 feet and may well be twice that figure, but his section seems to include at the base some units that other workers include in the Piegan Group or in the Helena.

The main body (Ross) is correlated with the Snowslip, Shepard, and Shields Formations and the Bonner Quartzite (Red Plume Quartzite in Marias Pass area). In the Flathead region the pale-pink quartzite is correlative with the upper part of the Red Plume Quartzite.

GRAYISH-GREEN ARGILLITE

Ross (1959) described green argillite (p€ga), which becomes increasingly gritty upward in the section, overlying red to pink crossbedded quartzite (p€q) and underlying Flathead Quartzite. Where the sequence crops out on a ridge top 5 miles northwest of Chair Mountain, it is several hundred feet thick. The unit is shown separately on Plate 3 wherever Ross identified and mapped it. This sequence of green argillite is believed to be correlative with part of the Roosville Formation of the Whitefish Range, with the "unnamed sequence" near Marias Pass (Childers, 1963), and with the McNamara Formation in the central Swan Range.

UNNAMED SEQUENCE (CHILDERS)

Childers (1963) described a sequence of poorly exposed green argillite and quartzite and sparse gray calcareous shale and sandstone overlying Red Plume Quartzite on the slopes of Blacktail and Red Plume Mountains. The sequence is about 500 feet thick and is tentatively correlated with the grayish-green argillite sequence (Ross, 1959) and with the McNamara Formation of the Swan Range.

MILLER PEAK ARGILLITE

In the southwest quarter of the Saypo quadrangle, Deiss (1943a, p. 215) described the Miller Peak argillite as pale-green and maroon fissile siliceous argillite, red and green sandy ripple-marked argillite, buff-tan dolomite, and quartzose sandstone. Upper beds of the Miller Peak, amounting to several hundred feet of strata, consist of carbonate-bearing and quartzose sandstone and red-green argillite constituting a transition zone into the overlying Cayuse Limestone. Deiss estimated the Miller Peak to be 1,000 feet thick, but the lower part of the unit is cut out by the Lewis Thrust.

The Miller Peak is correlative with the Snowslip Formation (Pl. 3), and with the red and tan siltstone that is the lowest unit of the Hoadley Formation, as that term is used by Mudge (1966). In the Silvertip quadrangle the Miller Peak Argillite is mapped as the lowest unit of the Missoula Group ($p€m_1$) (Pl. 3).

CAYUSE LIMESTONE

Above the Miller Peak is the Cayuse Limestone, a finely crystalline siliceous dull- to pale-gray dolomite interbedded with maroon and greenish-gray fissile argillite and gray coarse-grained quartzite. Overlying the dolomite and argillite is brown-weathering dolomite and black-gray fissile argillite, followed by calcareous and dolomitic argillite and sideritic and dolomitic marble. The upper part of the Cayuse consists of blue and dull-gray oolitic limestone, thick-bedded crystalline limestone, and thin-bedded algal limestone. Algal heads range from 6 to 30 inches in diameter.

From reconnaissance traverses across the strike, Deiss scaled a thickness of 1,000 feet for the Cayuse Limestone. This unit is correlative with the Shepard Formation and with the middle Missoula Group (p€m_m) (Pl. 3).

HOADLEY AND AHORN FORMATIONS

Conformably overlying the Cayuse is the Hoadley Formation (Deiss, 1943a), the basal part of which consists of green, green-gray, and maroon argillite and fine-grained quartzite weathering gray and green. Above the basal unit is sandy and calcareous argillite gradational into pale-green calcareous sandstone and argillite. Higher in the section are red, pink, and buff sandstone and argillite. Above the red and pink sandstone sequence is buff-weathering calcareous, sericitic, and limonite-bearing argillite and argillaceous limestone, followed by dark- and brilliant-red ripple-marked sandstone and sandy pale-red argillite.

The Hoadley was described by Deiss as 4,100 feet thick, but this unit is equivalent to only the top two members of the Hoadley, as that term was used by Mudge (1966). It is also equivalent to the Shields Formation and to the lower part of the upper Missoula Group (p€m_u) (Pl. 3).

Uppermost Belt unit in the Lewis and Clark Range is the Ahorn Quartzite (Deiss, 1943a), described as the youngest of the Belt formations, as it underlies Flathead Quartzite (Cambrian) in the Silvertip area. The Ahorn consists of (lower) pink and pale-maroon crossbedded and vitreous thick-bedded quartzite, and (upper) green and red argillite. The top unit is dominantly interbedded green and green-gray fissile argillite containing surbordinate thin-bedded red-gray argillite intercalcated with a few beds of fine-grained sandstone.

Deiss estimated the thickness of the Ahorn to be 2,100 feet, and Mudge's equivalent Ahorn Sandstone (subdivided into two members) is 1,350 feet thick. The Ahorn is equivalent to the Bonner and McNamara Formations (McGill and Sommers, in Mudge, 1966, and in this report); to the Red Plume Quartzite and "unnamed sequence" in the Marias Pass area (Childers, 1963); and to the upper part of the Upper Missoula Group of the Silvertip area (p€m_u) (Pl. 3).

PALEOZOIC STRATA

Prior to 1931 two sections of Cambrian rocks in northwest Montana had been published, one measured on the Dearborn River and one at Gordon Mountain (Walcott, 1917b). Between 1931 and 1943 Deiss and his co-workers did detailed and reconnaissance studies of Paleozoic rocks in the Sawtooth and Lewis and Clark Ranges. Sloss and Laird, prior to 1947, studied Mississippian and Devonian formations in northwestern Montana. Mudge and others (1962) studied Mississippian rocks in the Sawtooth Range, and Mudge (1965, 1966) published geologic maps covering most of the south half of the Saypo 30-minute quadrangle.

Within the Whitefish Range, Willis (1902), Daly (1912), Sweeney (1955), and Barnes (1963) reported on Paleozoic and Mesozoic rocks. Price (1962) described Paleozoic rocks along the International Boundary and in the Fernie map area of southern Alberta and British Columbia.

In western Lincoln County, Calkins and MacDonald (1909) recognized the Paleozoic aspect of the limestone and shale in Swamp Creek valley, and Gale (1934) assigned to these Swamp Creek rocks a Middle Cambrian age based on fossil content. Rector (1963) described lower Paleozoic rocks in the Fishtrap Creek area of northern Sanders County.

Paleozoic rocks are exposed in the northwestern and northeastern parts of the Whitefish Range of northern Flathead County and in the Flathead and Lewis and Clark Ranges of southeastern Flathead County. In Lincoln County a fault block of lower Paleozoic rocks is present along Swamp Creek, about 25 miles southeast of Libby. At the headwaters of McGinnis Creek, very near the Lincoln-Sanders County line, light-gray limestone is exposed; it is believed to be of Cambrian age. Paleozoic rocks are poorly exposed in the Whitefish Range and in western Lincoln County, but exposures in southeast Flathead County are better.

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

Paleozoic rocks, especially cliff-forming limestone, contrast in topographic expression and in color to the more subdued rocks of the underlying Belt Series. West-facing Paleozoic cliffs in afternoon sunlight exhibit a distinctive pale yellowish gray, above underlying Belt strata that are dark grayish red or dark gray.

Paleozoic sedimentary rocks of Cambrian, Devonian, and Mississippian age crop out in parallel northwest-trending belts in the Flathead and Lewis and Clark Ranges (Pl. 2 and 3). They crop out between Big Salmon Lake and Meadow Creek landing field; along the east side of the South Fork from Black Bear Creek to Twin Creek, and on the western slope of the Continental Divide from the Flathead-Powell County line north to Whitcomb Peak. Another belt of Paleozoic rocks follows the Continental Divide from the head of Spotted Bear River north past Pentagon Mountain, thence beyond Cruiser Mountain to latitude 48°. Outcrops of Paleozoic strata are separated by outcrops of Beltian rocks of the Missoula Group. Northeast of Spotted Bear a small mass of Paleozoic strata crops out near latitude 48° (Pl. 3).

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

CAMBRIAN—WESTERN LINCOLN COUNTY

Along Swamp Creek south of Cliffside are red and gray shale and sandy shale overlain(?) by massive dark- and light-gray dolomite and magnesian limestone. On the west side of U.S. 10, north of Cliffside, occurs massive dark-gray limestone having a very fetid odor when broken. Other dark- and light-gray massive dolomite opposite the mouth of Houghton Creek has a lower Paleozoic aspect, but no fossils were found in these beds.

Fragmentary specimens of *Hyolithes*, a few brachiopods, and trilobites of the *Glossopleura* zone were found in the shale and sandy shale in the NE¼ sec. 15, T. 28 N., R. 30 W. Gale (1934, p. 179) concluded that the red and gray fossiliferous sandy shale in the area represented the Gordon Formation (Middle Cambrian), and is in part equivalent to the Spence and Wolsey Shales. The shale has been contorted and is irregular in attitude; the general strike of the beds is N. 25° W., 40° E. The section seems to be overturned, and a sandstone above the sandy shale may represent the upper part of the Flathead Sandstone. This Paleozoic section, exposed in a fault block bounded by Belt strata, extends north to the valley occupied by Libby Creek, where it is covered by glacial gravel.

At the headwaters of McGinnis Creek, in the S½ S½ sec. 9 and in sec. 16, T. 25 N., R. 28 W., light-gray massive siliceous dolomite, mapped as lower Paleozoic, is poorly exposed, as the area is covered with soil. No fossils were found in the dolomite. The described area is believed to be bounded by faults on the north and west.

CAMBRIAN—NORTHERN FLATHEAD COUNTY

Cambrian rocks exposed in the Tuchuck area of the northeastern part of the Whitefish Range comprise a basal sandstone, a middle shale, and an upper limestone. Barnes (1963, p. 56) described the basal sandstone as composed of light-gray coarse- to medium-grained quartz sandstone about 100 feet thick, which weathers pale red and white. The unit is blocky to slabby, and no fossils were found in it.

The fissile middle shale is greenish gray and grayish red, and it is less resistant to erosion than either the basal sandstone or the overlying limestone. Barnes (1963) estimated the thickness to be about 150 feet. This unit shows evidence of flowage and deformation, and locally contains blocks of medium-gray limestone, possibly fragments of thin limestone beds contained in the shale.

The upper limestone unit is massive dark-gray mottled dolomitic limestone about 180 feet thick, which weathers very light gray. This unit is overlain by Devonian rocks, and the contact seems to be sharp but concordant (Barnes, 1963, p. 57).

CAMBRIAN—SOUTHEAST FLATHEAD COUNTY

FLATHEAD SANDSTONE

The Flathead was named by Weed (1900, p. 285) for an outcrop in the Little Belt Mountains. The unit was later amended by Deiss (1936, p. 1328) for central Montana; as amended, the term Flathead is generally applicable in northwestern Montana. In the map area and throughout Montana it is the lowest Cambrian unit exposed and is of Middle Cambrian age (Fig. 9).

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

The Flathead Sandstone is a medium-grained light-brown crossbedded, limonite-flecked, thin- to thick-bedded unit consisting mostly of quartz sand and white, tan, and colorless pebbles. Some

	Whitefish (Smith and Barnes)	Northern Lewis and Clark (Deiss)	Central Lewis and Clark and Sawtooth (Mudge)	Southern Lewis and Clark (Sloss and Laird)
Recent	Alluvium	Alluvium	Alluvium	Alluvium
	Glacial deposits	Glacial deposits	Glacial deposits	Glacial deposits
Tertiary	Kishenehn Formation			
Cretaceous	Kootenai Formation	Kootenai Formation		
Jurassic	Fernie Shale			
Triassic	Spray River(?) Formation			
Permian-Pennsylvanian	Rocky Mountain Quartzite			
Mississippian	Rundle Group: Etherington Limestone	Hannan Limestone	Castle Reef Dolomite	Unit MA
	Rundle Group, Mount Head Fm: Carnarvin (Yakinikak) Ls			
	Rundle Group, Mount Head Fm: Marston Ls and Sh			Unit MB_1
	Rundle Group, Mount Head Fm: Loomis Ls and Dol			
	Rundle Group, Mount Head Fm: Salter Dol		Allan Mountain Limestone	Unit MB_2
	Rundle Group: Livingstone Formation			
	Banff Limestone			Unit MC
- - - - - - - - - -	Exshaw Shale	Silvertip Cg at base		
Devonian	Devonian undifferentiated		Three Forks Formation	Unit DA_1
		Spotted Bear Limestone	Jefferson Formation	Unit DA_2
		Lone Butte Limestone		
		Coopers Lake Limestone		Unit DB
		Glen Creek Shale	Maywood Formation	Unit DC
		White Ridge Limestone		
Cambrian	Cambrian undifferentiated	Devils Glen Dolomite	Devils Glen Dolomite	Devils Glen Dolomite
		Switchback Shale	Switchback Shale	
		Steamboat Limestone	Steamboat Limestone	
		Pentagon Shale		
		Pagoda Limestone	Pagoda Limestone	
		Dearborn Limestone	Dearborn Limestone	
		Damnation Limestone	Damnation Limestone	
		Gordon Shale	Gordon Shale	
		Flathead Sandstone	Flathead Sandstone	

Figure 9.—Paleozoic, Mesozoic, and Cenozoic rocks in eastern Flathead County.

limonite blebs occur in bedding planes. In some localities the basal bed of the unit is crossbedded material as much as 5 feet thick containing white, tan, and colorless pebbles averaging ⅜ inch in diameter.

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

The upper half of the Flathead is more sandy, and near the top of the unit, shale is interbedded with the sand. The contact between the Flathead and Gordon is transitional, and previous workers have placed the contact at the base of the first consistent shale, although some sandy beds may occur above the contact.

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

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

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

GORDON SHALE

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

Deiss (1936, p. 1328) emended the definition of the Wolsey Shale of central Montana and stated that it applied in most particulars to the Gordon Shale of northwest Montana (Deiss, 1939, p. 37). He wrote "The most notable differences between the Gordon and Wolsey Shales is the absence from the Gordon of numerous extremely fossiliferous limestone lenses, the slightly greater proportion of limestone and sandstone in thicker beds in the upper middle part of the formation, and the absence or paucity of fossils in the limestones and sandstones."

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

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

On Whitcomb Peak in the Flathead Range, a pace-and-brunton survey of an incomplete section of the Flathead Sandstone and the complete Gordon Shale gave an approximate thickness of 35 feet (faulting cuts out the basal part of the unit) for the Flathead and about 345 feet for the Gordon (Fig. 10). The above-average thickness of the Gordon Shale may result from local thickening or from repetition through faulting.

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

Fossiliferous Gordon Shale crops out east of Hungry Horse Reservoir about midway up Twin Creek.

CAMBRIAN UNDIFFERENTIATED

Between the Gordon (Middle Cambrian) and the Devils Glen Dolomite (Upper Cambrian) are six conformable formations whose type localities are within the Lewis and Clark Range northwest of Monitor Mountain. They are, in ascending order, Damnation Limestone, Dearborn Limestone, Pagoda Limestone, Pentagon Shale, Steamboat Limestone, and Switchback Shale. Where the units of Middle and Upper Cambrian age were not divided they were mapped as Cambrian undifferentiated.

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

Conformably overlying the Damnation Limestone is the Dearborn Limestone, consisting of a lower shaly section and a thicker limestone section above. Within the area where Deiss measured sections, he gave (1939, p. 40) an average thickness of 298 feet for this formation. Basal green fissile shale in which limestone conglomerate beds are intercalated is overlain by green fissile shale and limestone containing, in some areas, interbedded calcareous sandstone. The upper part of the Dearborn is gray, grayish-brown, and tan thin- and thick-bedded limestone containing light-colored sandy nodules and clay flakes in some sections. The type locality for the Dearborn Limestone is on the north slope of the North Fork of Dearborn River in the Coopers Lake quadrangle. Sixteen species of trilobites have been identified by Deiss (1939, p. 39) in the lower part of the formation.

The Dearborn Limestone is transitional into the conformably overlying Pagoda Limestone, which consists of a thin-bedded shaly basal unit overlain by a thick-bedded partly oolitic limestone. Thickness of the Pagoda averages 305 feet. The type locality is the upper southeast slope of Prairie Reef. In the lower 70 or 75 feet, beds of dull-green fissile shale are interlayered with gray, green-gray, and tan sandy and pure limestone containing buff and olive-green clay nodules and flakes. The upper part of the Pagoda is thin- and thick-bedded cream-color and grayish-brown fine-grained limestone whose central part is oolitic. Deiss listed 24 species of trilobites collected from the Pagoda Limestone.

Pentagon Shale in the eastern part of the map area (Pl. 3) extends for an undertermined distance north of Pentagon Mountain, and to the south the unit was traced for a distance for 14 miles (Deiss, 1939, p. 42). Thickness of the Pentagon Shale ranges from 75 to 290 feet. This shale

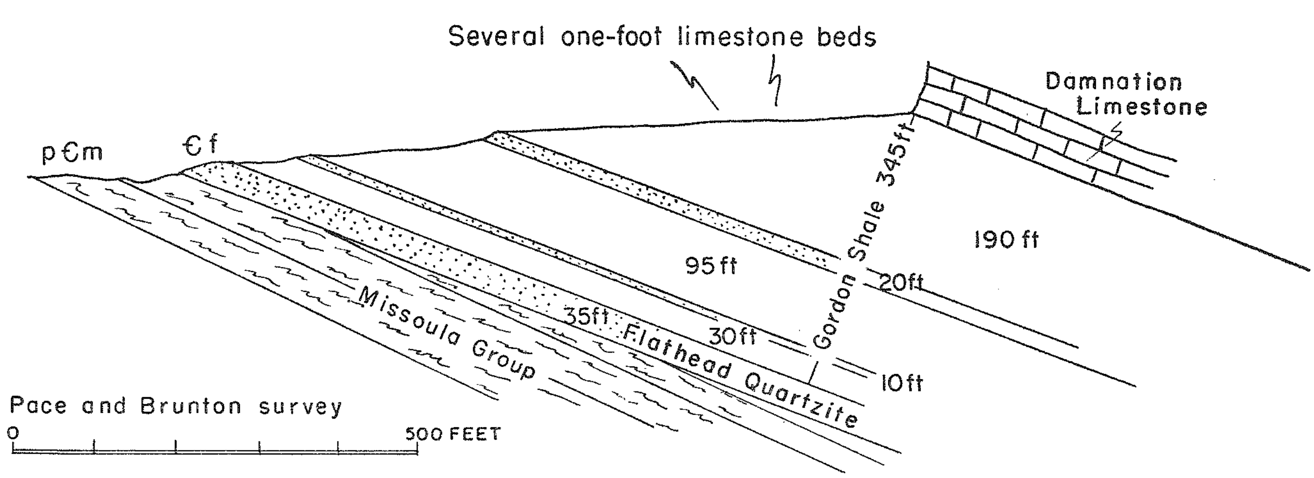


Figure 10.—Profile of Flathead and Gordon Formations, Whitcomb Peak.

unit is not recognizable in the central and south parts of northwest Montana south of Cliff Mountain, 18 miles south of Pentagon Mountain. Its type locality is 2 miles southeast of Pentagon Mountain along the Continental Divide in the Lewis and Clark Range. The formation is conformable on the Pagoda Limestone. It consists of a bottom member of calcareous gray and buff-tan-gray thick-bedded platy shale interlayered with blue-gray platy limestone, overlain by tan and blue-gray argillaceous limestone. Above the limestone is black-gray paper shale, becoming greenish-brown toward the top, interbedded with thin limestone beds near the base and containing a thick limestone bed near the top. Grayish-white and brown nodular and platy argillaceous limestone makes up the uppermost 26 feet of the Pentagon Shale. Trilobites and brachiopods are concentrated in large numbers in the lower half and uppermost part of this member.

In the north part of the area (Pl. 3) the Steamboat Limestone conformably overlies the Pentagon Shale, but in the south part of the map area, where the Pentagon Shale is absent, the Steamboat conformably overlies the Pagoda Limestone. Thickness of the Steamboat Limestone averages 274 feet. The type section is on the crest of Prairie Reef in the Lewis and Clark Range, 5 miles east of the map boundary. The Steamboat Limestone is a medium- and dark-gray massive to thick-bedded cliff-forming formation containing several layers of dull-green fissile shale and shaly limestone. Deiss listed 14 species of the *Kochaspis upis* fauna as characteristic of this formation.

Conformably overlying the Steamboat Limestone is the Switchback Shale. It attains a maximum thickness of 253 feet east of Kid Mountain, but the average thickness in other sections is 111 feet. The type section is in the Ovando quadrangle on a ridge east of Kid Mountain and on the southwest flank of Gordon Mountain in the SW¼ sec. 9, T. 19 N., R. 13 W. Deiss mentioned only unidentifiable fossil fragments found in the limestone beds of the Switchback Shale. The lower one-third to one-half of the formation is dominantly soft fissile green and gray slightly calcareous and arenaceous shale interbedded with gray crystalline rusty-weathering limestone. The upper part of the unit is gray and brown arenaceous fine-grained magnesian limestone forming angular fragments and weathering buff.

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

Within the Twin Creek area, rocks overlying the Gordon Shale include the Damnation Limestone, Dearborn Limestone, and Pagoda Limestone, but the lower part of the Dearborn and the Pagoda contain much less shale here than in the southern part of the Lewis and Clark Range. Massive cliff-forming finely crystalline medium-gray limestone weathering light gray and containing irregular yellowish cavities is believed to represent the Dearborn Limestone in the Twin Creek area. Interbedded with the limestone layers are a few 3-inch beds of feldspathic quartz sandstone. Cambrian rocks strike N. 5° to 20° W. and dip 32° to 40° E.

Palmer* expressed the opinion that post-Cambrian rocks overlie the Pagoda Limestone in the Twin Creek area. He stated:

"In the Twin Creek area, the Pagoda is apparently overlain by post-Cambrian rocks, as the younger rocks are not typical of the Cambrian of the region. However, we did not see any direct faunal evidence that would determine the age of the post-Pagoda rocks . . . the Gordon is equivalent only to the basal Wolsey . . . and the Wolsey-Meagher contact is essentially the contact between the upper and lower members of the Pagoda of Deiss. The Damnation and Dearborn Limestones tongue out eastward into the Wolsey."

DEVILS GLEN DOLOMITE

Deiss (1933, p. 40) named this upper unit of Late Cambrian age the Devils Glen Dolomite from its type locality on a north spur of Monitor Mountain near Devils Glen, an inaccessible boulder-filled canyon on the North Fork of Dearborn River. From the vicinity of Pentagon Mountain, where it is 179 feet thick, this dolomite thickens toward the Dearborn River, where it attains a thickness of 565 feet. Deiss gave an average thickness of 353 feet for the formation throughout northwest Montana. It conformably overlies the Switchback Shale, but an erosional unconformity separates the Devils Glen from overlying Devonian rocks. Deiss (1938, p. 1076) assigned the Devils Glen Dolomite a Late Cambrian age. The formation is unfossiliferous thick-bedded to massive cliff-forming grayish-white dolomite

* A. R. Palmer, 1965, letter of 11/3/65 to W. M. Johns, regarding results of reconnaissance trip to Cambrian section in Twin Creek area.

that weathers to dull grayish white; the lower part is thinner bedded and contains smaller amounts of magnesia. Locally, the surfaces are spotted pink, and Deiss reported that several thin-sections examined microscopically contained finely disseminated quartz grains.

Within the Pretty Prairie quadrangle of northwestern Lewis and Clark County, Mudge (1966) mapped separately the Flathead Sandstone, Gordon Shale, Damnation Limestone, Dearborn Limestone, Pagoda Limestone, Steamboat Limestone, Switchback Shale, and Devils Glen Dolomite. He placed the contact between Middle Cambrian and Upper Cambrian within the Switchback Shale. Reported total thickness of Middle and Upper Cambrian rocks in the quadrangle ranges from 1,750 to 2,000 feet.

DEVONIAN—NORTHERN FLATHEAD COUNTY

In the northwestern part of the Whitefish Range, near the International Border about 7 miles north of Eureka, is an east-dipping sequence about 1,300 feet thick consisting of calcareous quartzite 300 feet thick overlain by massive fetid fossiliferous dark-gray limestone (Sommers, 1961, p. 28). Daly (1912) had assigned a Devonian age to these rocks on the basis of their fossils, and Sommers described the sequence as Devonian. Leech (1960) correlated these beds with the Palliser Formation (Upper Devonian) and with Mississippian beds.

In the northeastern part of the Whitefish Range, Devonian rocks occur in a glide block about a mile south of Tuchuck Mountain. Barnes (1963, p. 57) described a well-exposed lower portion consisting of medium-light brownish-gray mottled finely crystalline dolomite and dolomite breccia, which weather light gray or medium brownish gray and have a bituminous odor. Thickness is estimated to be 2,000 feet. Approximately 1,300 feet above the base is a lighter-weathering dolomitic siltstone and sandstone marker unit, possibly equivalent to the Alexo Formation of the Alberta Rockies.

DEVONIAN—SOUTHEASTERN FLATHEAD COUNTY

In part of the eastern half of the Silvertip quadrangle, Deiss (Pl. 3) subdivided the Devonian strata and mapped as one unit the White Ridge and Glenn Creek Formations (Dwg) and as another unit all the overlying Devonian limestone beds. In the northwest part of the Silvertip quadrangle and northwestward, Devonian strata were not subdivided, and Devonian rocks are mapped as Devonian undifferentiated. Deiss (1943a, p. 228) regarded the Devonian strata in northwest Montana as entirely of Late Devonian age.

While studying Devonian rocks in central and northwest Montana during 1944 and 1945, Sloss and Laird realized that stratigraphic terminology used in central Montana was not applicable in the northwestern part of the state. Devonian strata encountered by drilling were assigned to units designated units C, B, and A from base to top (Fig. 9), unit A being further subdivided into a lower A_2 unit and an upper A_1 unit (Sloss and Laird, 1947, p. 1418).

The basal Devonian unit C is separated from the underlying Devils Glen Dolomite (Cambrian) by an erosional disconformity, unit C strata having been deposited on a channeled surface. The unit C was correlated with the Glenn Creek and White Ridge Formations of Deiss, which can be recognized only locally (Sloss and Laird, 1947, p. 1419).

WHITE RIDGE LIMESTONE—GLENN CREEK SHALE

The White Ridge and Glenn Creek Formations have type localities on White Ridge on the 113° meridian at the head of Glenn Creek, tributary of the North Fork Sun River and about 6 miles east of the Continental Divide. Here on the southern flank of the southwestern peak of White Ridge, the Glenn Creek Shale overlies the White Ridge Limestone, the names being taken from Glenn Creek and White Ridge on the border between the Silvertip and Saypo quadrangles.

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

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

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

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

UPPER DEVONIAN LIMESTONE

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

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

Strata mapped as Upper Devonian limestone undifferentiated consist of the Coopers Lake, Lone Butte, and Spotted Bear Limestones. The Coopers Lake includes basal beds of thick-bedded to massive brown sandy limestone, becoming in some zones calcareous sandstone interbedded with thin layers of buff shale, overlain by thick-bedded to shaly fossiliferous tan-gray limestone, which is in turn overlain by thick-bedded to massive fine-grained brown to tan limestone. Some interbeds of calcareous clay shale are associated with the basal part of the brown-tan limestone. The upper limestone zones are in part petroliferous; when the rock is broken a fetid odor is detectable, as is common in Devonian rocks in the area. The upper zones tend to weather gray and buff. The fossiliferous tan-gray limestone contains brachiopods, corals, and stromatoporoids resembling those in the Jefferson Limestone. This part is about 337 feet thick.

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

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

A 35-foot breccia zone in the Twin Creek-Spotted Bear River area is believed to be correlative with Deiss' Silvertip breccia conglomerate and part of the "evaporite-solution breccias" that Sloss and Laird (1947, p. 1422) assigned a late Devonian age. This breccia may well be of late Devonian age, but to maintain continuity of mapping between the Silvertip and Swan Lake regions, it has been assigned to the basal Mississippian, following Deiss' stratigraphic nomenclature.

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

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

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

No attempt was made to subdivide Devonian rocks in the Flathead Range north of Spotted Bear. Rocks tentatively assigned to Devonian age are exposed below the junction of Flat Creek and Twin Creek and midway up the North Fork of Twin Creek. Cropping out in these areas is medium-bedded medium-gray limestone that weathers light gray and has a petroliferous odor. Below the mouth of Flat Creek is finely crystalline yellow-gray dolomite that weathers light gray and yellowish gray. These rocks are medium bedded, and weathered surfaces exhibit irregular shallow pits. This unit is moderately resistant so that it forms cliffs; it has a petroliferous odor on fresh surfaces.

In the Sawtooth Ridge quadrangle of northwest Lewis and Clark County and southwest Teton County, Mudge (1965) divided the Devonian into the Jefferson Formation and the overlying Three Forks Formation, the Jefferson consisting of a lower dolomite member and the upper Birdbear Member. Mudge assigned a thickness of 700 feet to the Jefferson and 250 feet to the Three Forks Formation.

MISSISSIPPIAN—NORTHERN FLATHEAD COUNTY

Mississippian rocks crop out over extensive areas in the northeast part of the Whitefish Range (Pl. 2), where they are virtually confined beneath the Hefty thrust on the eastern slopes of Mount Hefty.

The terminology used by Price (1962, p. 19-23) in the Fernie map area, 25 miles north of the International Boundary, was extended to the Whitefish Range by Barnes (1963), who correlated Mississippian units having type sections in southwestern Alberta with Mississippian rocks in the Whitefish Range.

Mississippian rocks exposed in the Whitefish Range (Pl. 2) include the Banff Formation, and the overlying Rundle Group, which in ascending order includes the Livingstone Formation, the Mount Head Formation, consisting of the Salter, Loomis, Marston, and Carnarvon Members, and the uppermost formation of the Rundle Group, the Etherington Formation. The Exshaw Formation, which underlies the Banff, may be present but is not exposed.

The following descriptions of Mississippian units were obtained from Barnes (1963, p. 58-64).

BANFF (AND EXSHAW?) FORMATIONS

The Banff Formation is exposed on the east slope of Mount Hefty in a slice beneath the Hefty thrust and in the valley of Tepee Creek east of the Tuchuck fault. Lower Banff rocks include dark-gray shaly strata, which are poorly exposed in the Tepee Creek-Mount Hefty area. At neither of these locations was the lower part of the formation well enough exposed that Barnes could verify the presence of the Exshaw Shale below the Banff.

Upper Banff rocks are medium-brownish-gray finely crystalline limestone having a bituminous odor; irregular layers of gray chert make up about one-third of the rock. Interbedded with the finely crystalline limestone is medium-light-gray bioclastic calcarenite that weathers light gray. Brachiopods are common in the Banff, especially in the crystalline limestone.

LIVINGSTONE FORMATION

The Livingstone Formation, basal unit in the Rundle Group, occurs as brecciated and recrystallized carbonate in a thrust slice east of Mount Hefty, within the core of an anticline, and in Tepee Creek valley.

This formation includes medium- and light-gray very coarse grained bioclastic calcarenite consisting of crinoid plates and less abundant bryozoan fragments interbedded with medium-light-gray medium-crystalline limestone. Irregular light-gray chert layers are present in the calcarenite. In the upper part of the formation, cliff-forming massive calcarenite seems to grade into silty and sandy dolomite of the basal part of the Mount Head Formation (Barnes, 1963, p. 60). The formation is estimated to be 1,500 feet thick.

MOUNT HEAD FORMATION

Within the Whitefish Range the Mount Head Formation is about 700 feet thick and consists of a sequence of limestone and dolomite layers interbedded with a minor amount of shale. Barnes recognized four of the six members of the formation described by Douglas (1958, p. 42-60) in the Mount Head map area of Alberta. In ascending order they are the Salter, Loomis, Marston, and Carnarvon Members, all of which are moderately widespread in the northeast part of the Whitefish Range (Pl. 2).

The basal unit is the Salter Member, which consists of light-gray, light-brownish-gray, and medium-gray finely crystalline silty and sandy dolomite and interlayered medium-gray finely crystalline limestone. Some bioclastic calcarenite is present in minor amount. Chert forms patches and nodules elongate parallel to lamination planes (Barnes, 1963, p. 60). The contact between the Salter and Loomis Members is gradational.

Loomis rocks can be distinguished from the Salter and Marston Members because they characteristically form rounded light-gray cliffs. This member is composed of light-gray medium to very coarse grained bioclastic calcarenite interbedded with medium-gray and medium-dark-gray limestone and dolomite. Some carbonate and calcarenite beds are bituminous. The contact with the overlying Marston Member is sharp.

The Marston Member, being nonresistant, tends to form recessive slopes above the cliff-forming Loomis Member. The Marston contains medium-dark-gray and dark-gray finely crystalline compact limestone interbedded with dark-gray, brownish-gray, and black dolomitic mudstone and shale a few centimeters thick. Solution pitting is common on weathered surfaces. The contact with the overlying Carnarvon Member is gradational.

Carnarvon rocks in the northeast part of Flathead County form persistent steplike cliffs; thickness of the unit is about 200 feet. The strata include interbedded medium- to dark-gray and subordinate light-gray cryptocrystalline limestone interlayered with light-gray to medium-dark-gray microcrystalline limestone. Limestone breccia and calcarenite is associated with the microcrystalline carbonate rock. Vugs and lenselike pits 2 mm to 3 cm across and filled with calcite are common; weathering of the calcite leaves the rock surfaces characteristically pitted. On fresh surfaces a faint bituminous odor can be ordinarily detected. Near the top of the Carnarvon Member silicified corals are present. Productid brachiopods occur in the upper part of the sequence. The coral-bearing beds are cherty, and some chert nodules seem to have replaced corallites.

Barnes (1963, p. 62) stated: "Willis (1902, p. 324-325) described carboniferous limestones in Yakinikak Creek valley which he named the Yakinikak limestone. He erred in appraising the stratigraphic relationships of this limestone with the Rocky Mountain Formation and the Belt Series, but from his descriptions it seems most likely that the Yakinikak limestone is the Carnarvon Member."

Barnes (1963) described the contact between the Carnarvon and the overlying Etherington Formation as gradational and placed the contact where medium-gray microcrystalline limestone is overlain by the first thick light-gray calcarenite of the Etherington Formation.

ETHERINGTON FORMATION

The Etherington Formation is the uppermost formation of the Rundle Group and is a weakly resistant formation, in contrast to the cliff-forming Carnarvon Member of the Mount Head Formation. The unit is best exposed along the banks of the Frozen Lake fire road through the forested benchland between Frozen Lake and Mount Hefty.

Basal rocks of the Etherington are medium-gray and medium-light-gray crystalline limestone and calcareous dolomite containing nodular masses or irregular patches of chert. The central part of the formation is massive coarse-grained and crossbedded medium-gray bioclastic calcarenite forming blocky cliffs. It weathers grayish yellow or light gray. The calcarenite is composed of crinoid plates and columnals and bryozoan fragments. Upper beds of the Etherington are finely crystalline dolomitic limestone and sandy, medium-gray cherty limestone interbedded with some bioclastic calcarenite.

Barnes (1963) described the thickness of the Etherington Formation as extremely variable, ranging from 200 to 500 feet. Where the unit is thick, the contact with the overlying Rocky Mountain seems to be gradational; where the unit is thin, the contact seems to be disconformable. Sweeney (1955, p. 17-21) measured in detail a stratigraphic section of the uppermost 460 feet of beds in the Rundle Group in sec. 25, 26, 35, and 36, T. 37 N., R. 23 W.

MISSISSIPPIAN—SOUTHEASTERN FLATHEAD COUNTY

Mississippian rocks are generally present as erosional remnants capping peaks and higher elevations within the Flathead and Lewis and Clark Ranges. Mississippian strata crop out on Spotted Bear Mountain, Lone Butte, Pentagon Mountain, and Table Mountain, and opposite Wall Creek adjacent to the east side of Spotted Bear River. East of the upper end of Hungry Horse Reservoir, strata of probable Mississippian age crop out east of Beacon Mountain near the head of Twin Creek. Deiss, in a preliminary subdivision of Mississippian rocks, separated them into five members, collectively equivalent to the Madison Limestone, but later (1943a, p. 229) proposed a new name, Hannan Limestone, from a type section in Hannan Gulch within the Sawtooth Range in the Saypo quadrangle. He believed that most of the Mississippian limestone in the Saypo quadrangle was equivalent to the Madison Limestone but that upper beds contained Meramec and Chester fossil species, indicating a later Mississippian age.

Stratigraphic and paleontological studies of Mississippian rocks in the southern Sawtooth

Range within the Sun River Canyon area confirmed the Meramec age of the upper part of the Mississippian sequence, but Chester equivalents were not found (Mudge and others, 1962, p. 2004). These authors recognized the Mississippian rocks of the Saypo area as equivalent to the Madison Group and subdivided them into two new formations—the Allan Mountain Limestone as the lower formation, which on the basis of faunal zones is tentatively believed to be the same age as the Lodgepole Limestone of southwestern Montana, and the Castle Reef Dolomite as the upper formation, approximately the same age as the Mission Canyon Limestone. The lower formation is divided into three unnamed members, the upper formation into an unnamed lower member and the redefined Sun River Member. They suggested that the name Hannan Limestone be abandoned. These revisions of nomenclature postdate Deiss' mapping in the Flathead and Lewis and Clark Ranges, and a study of the type section of the Allan Mountain Limestone and Castle Reef Dolomite to permit revision of Deiss' mapping of Mississippian outcrops was not possible in the time allotted for reconnaissance mapping for this report. Therefore, the name Hannan Limestone was retained for Mississippian rocks, although it was realized that in future work, nomenclature for the Mississippian rocks should conform to that proposed by Mudge and associates.

HANNAN LIMESTONE

In preliminary work the Hannan Limestone was subdivided by Deiss in ascending order into the Silvertip Conglomerate, Saypo Limestone, Dean Lake Chert, Rooney Chert, and Monitor Limestone. Sloss and Laird (1945) separated the Mississippian units by letter and number, which in ascending order are MC, MB, and MA (Fig 9), Unit MA being present only in the Sawtooth Range and farther east; farther west it has been removed by erosion. Unit MC and the lower part of MB (MB_2) are the equivalents of Mudge's Allan Mountain Limestone. The upper part of unit MB (MB_1) and MA are equivalent to the Castle Reef Dolomite (Mudge and others, 1962, p. 2009-2017).

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

The basal Mississippian deposit is a breccia conglomerate. A thickness of 23 feet is exposed on Spotted Bear Mountain, and 30 to 35 feet near the head of Twin Creek. The breccia-conglomerate thickens southward from 40 feet at Pentagon Mountain to 140 feet at Lone Butte. The brecciated and conglomeratic material is composed of angular to subrounded pebbles to boulders of gray and brown fetid limestone in a matrix of crystalline gray limestone that weathers grayish white. In the southwest Saypo quadrangle, Deiss (1943a, p. 228) mapped a 3- to 7-foot intraformational breccia, which he correlates with this breccia-conglomerate.

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

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

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

Rooney Chert, which according to Sloss and Laird is approximately the same as their unit MB.

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

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

Sloss and Laird's unit MA occurs only as far west as the Sawtooth Range and has been removed by erosion in the Flathead and Lewis and Clark Ranges.

PERMO-PENNSYLVANIAN

ROCKY MOUNTAIN FORMATION

Rocky Mountain strata crop out in the Mount Thoma-Cleft Rock Mountain area and underlie gravel and siltstone-covered areas bordering the northern part of the Whitefish Range to the east. These quartzite strata are composed of clean and well sorted grains and should not be confused with overlying Mesozoic sandstone units.

A large part of the formation is believed to be composed of light-gray to very light gray or light-yellowish-gray fine-grained jointed unfossiliferous quartzite and quartzitic sandstone that weathers grayish yellow, grayish orange pink, or grayish pink. Crossbedding is a common feature, and ripple marks are present. The unit is not commonly exposed, but develops talus aprons on openly wooded mountains (Barnes, 1963, p. 64). In the upper part of the Rocky Mountain Formation, sandy and chert-bearing dolomite is interbedded with quartzite.

The thickness of the Rocky Mountain Formation in the Mount Thoma region is more than 600 feet (Barnes, 1963, p. 65). Sweeney measured a stratigraphic section in sec. 25, T. 37 N., R. 23 W., amounting to 718 feet, but the top is an erosion surface. Sweeney (1955, p. 22) estimated that between 650 and 859 feet of Rocky Mountain quartzite is exposed along the valley of Yakinikak Creek.

MESOZOIC

Mesozoic rocks occur beneath the Yakinikak thrust sheet within valleys draining eastward from the ridge south of Mount Hefty. Mesozoic rocks exposed in the northeast part of the Whitefish Range are strata of the Fernie Formation (Jurassic). Between the Fernie Formation and underlying Paleozoic rocks should be the Spray River Formation (Triassic), consisting of a thin siltstone and shale unit, but if it is present it is not exposed (Barnes, 1963).

JURASSIC

FERNIE FORMATION

Because the Fernie strata are incompetent, considerable structural deformation is localized within the formation. Beds are nonresistant to erosion, and the unit is poorly exposed. Because of the easy erodability, drainages are deeply entrenched in areas where the formation crops out.

Barnes (1963, p. 66) described Fernie rocks along the front of the Whitefish Range east of Mount Hefty as follows:

"The lowermost beds observed are grayish-black to brownish-black fissile shales containing abundant molds of belemnites. Isolated blocks of medium dark gray, sandy, bituminous, fine- to medium-crystalline limestone were found in the shale, probably disrupted by flowage of the shale from interbedded once continuous limestone beds. These limestone blocks often contain abundant belemnite phragmocones. Above these shales is an interval of medium- to light-gray fine-grained partly dark gray shales. The sandstones are rather poorly sorted and are flaggy to slabby, weathering yellowish gray. The upper part of the Fernie has been removed by erosion, and no later Mesozoic formations are exposed in the map area [northeast Whitefish Range]."

Barnes estimated the thickness of Fernie beds exposed southeast of Mount Hefty to be somewhat more than 500 feet.

Northeast of Mount Thoma the Fernie rocks are composed of brownish-gray, yellow-gray-weathering shale and medium-gray, medium-dark-gray, and dark-gray sandy shale and quartzitic siltstone. Thin interbeds of light-gray quartzite and medium-gray cryptocrystalline limestone in dark- to medium-gray shale were observed in the outcrop area. Fernie strata are believed to occur as fault blocks bounded by Rocky Mountain beds to the east and south and by Mississippian limestone to the north and west.

Across the International Boundary in southwestern Alberta and southeastern British Columbia, phosphorite and phosphatic shales occur in several zones in upper Paleozoic and Mesozoic formations (Price, 1962, p. 61).

Nodular and oolitic phosphate rock has been reported (1) in the shales of the lower Banff-Exshaw unit (Mississippian); (2) as black nodular and angular phosphate fragments incorporated in a grayish-yellow-brown and gray sandy nonphosphatic matrix contained in a 16-foot zone about 50 feet below the Rocky Mountain-Spray River contact (Permian), the zone being conformable with fine-grained light-gray calcareous and noncalcareous sandstone above and below; (3) as oolitic and nodular phosphorite and phosphatic shale 1 to 6 feet thick at the base of the Fernie Formation; and (4) in the Rock Creek Member of the Fernie Formation about 200 feet above its base (Jurassic).

CRETACEOUS

KOOTENAI FORMATION

An undetermined thickness of an incomplete section of Kootenai beds (Lower Cretaceous) crops out 6 miles northeast of Pentagon Mountain, where Kootenai strata are in fault contact with Miller Peak Argillite of the Missoula Group.

The Kootenai Formation was named by J. W. Dawson (1885) in Canada, and the lithologic equivalents of Dawson's Kootenai were mapped by Deiss in the southwest and northwest parts of the Saypo quadrangle, where he estimated a probable thickness of 900 feet. For the central Sawtooth Range, a probable maximum thickness of 1,500 feet (Deiss, 1943b, p. 1143) was recorded.

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

CENOZOIC

TERTIARY

In eastern Flathead County, Tertiary rocks (Kishenehn Formation) crop out in the valley of the Flathead River (North Fork) and in the valley of the South Fork Flathead River northwest of Spotted Bear. At these localities Tertiary strata are poorly exposed because of the nonresistant nature of the clastic rocks and the overlying gravel and alluvium mantle. On the basis of fresh-water mollusks and mammal remains collected by Russell (1954, 1955), Barnes assigned Kishenehn strata to very late Eocene and very early Oligocene time. He stated:

"Broad channeling is present in the formation where observed by the writer [Barnes]. It seems probable from lithologic and paleontologic evidence that the Kishenehn Formation was in large part deposited on a broad flood plain, in river channels, and in flood-plain lakes and swamps. The coarse, poorly sorted conglomerate facies, which is found at places along the edge of the present valley of the North Fork, may have been deposited by mud flows from the adjacent uplands. It is likely, then, that the Kishenehn Formation is not the remnant of a once extensive blanket deposit now preserved in a fault-bounded trough; but that the fault trough, much as it exists now, was the locus of deposition of the formation (1963, p. 70)."

KISHENEHN FORMATION

Several different types of rocks are characteristic of Kishenehn strata in the valley of the North Fork, where they extensively underlie moraine, glacial outwash, and alluvium. A common lithologic type consists of light-gray to very light gray very fine grained massive sandy siltstone or standstone that weathers light gray. Wood fragments, carbonized twigs, and rock fragments of green and maroon Belt argillite are common. The unit is calcareous and locally clayey. Less common is pale-brown or brownish-gray fine- and medium-grained moderately well sorted sandstone. Moderate-reddish-brown poorly sorted calcareous sandy and silty claystone interlayered with light-gray claystone is a fairly common type. Carbonaceous shale and lignite of dark-gray hues are interbedded with siltstone.

Along the west side of the valley of the North Fork where Yakinikak Creek and Tepee Creek emerge from the mountains are outcrop areas consisting of poorly sorted and poorly indurated conglomerate; some of the weathered boulders and cobbles of Belt rocks and Paleozoic limestone are enclosed in a yellow-brown claystone matrix. Similar poorly consolidated clastic rocks consisting of dark-gray-weathering thick-bedded coarse conglomerate of subrounded cobbles and boulders and lenticular conglomerate zones of mixed cobbles and coarse-grained sandstone are exposed in a cut bank of the South Fork about 2 miles northeast of Spotted Bear.

Barnes estimated the thickness of the Kishenehn to be at least several thousand feet. Daly (1912, p. 87) reported that the old Kintla exploration oil well 2 miles south of the mouth of Yakinikak Creek intercepted 700 feet of Kishenehn strata.

QUATERNARY

Quaternary deposits in the map area can be roughly divided into three categories: preglacial (?) terrace deposits, glacial deposits, and Recent alluvium. The alluvium is common as narrow bands bordering rivers and larger streams. Moraine and outwash deposits and lacustrine clay and silt are exposed extensively in valleys of the major drainages including the Kootenai and Fisher Rivers in Lincoln County. Moraine and outwash deposits and lacustrine silt and clay are extensive in the Rocky Mountain Trench. Terrace deposits of late Pleistocene age flank the valleys of the Kootenai River and the lower part of the Yaak River in western Lincoln County. Glacial moraine and outwash floor the valleys of the North Fork and South Fork Rivers.

GLACIAL DEPOSITS

Glacial deposits in the map areas consist of heterogeneous till or morainal material, outwash, glaciofluvial gravel, and stratified silt and clay of lacustrine origin. Lacustrine silt and clay are pale pink or buff and are characterized by their horizontal attitude and by laminae commonly 3 mm or less in thickness. Typical stratified clay and silt was found at altitudes between 3,600 and 3,800 feet about a quarter of a mile west of Loon Lake near the head of Seventeenmile Creek (sec. 15 and 23, T. 33 N., R. 32 W.). About 1 mile west of the confluence of the Yaak and Kootenai Rivers, lime-cemented pebble conglomerate rests on Wallace bedrock. The material is not extensive and may have been deposited at a temporary position of the shoreline of glacial Lake Kootenai. A bouldery lime-cemented conglomerate containing unsorted and partly cemented sand and gravel zones is exposed adjacent to U.S. Highway 2 near the mouth of East Fisher Creek, NW¼ sec. 9, T. 26 N., R. 29 W. No striated rocks were found in this exposure and the cemented conglomerate may be of fluvial origin.

Erdmann (1944, p. 75) described a remnant of silt on the southeast side of Teakettle Mountain at an altitude of 4,250 feet, probably representing the uppermost stage of a lake in which silt was deposited within the valleys.

Hall (1962, p. 13) reported that south of Sylvia Lake on the north side of the Hand Creek road, buff laminated lacustrine silt is exposed at altitudes of 4,800 to 5,000 feet. The silt may have been deposited in a proglacial lake as a result of ponding by ice and morainal debris in the valley of Sylvia Lake and by ice in Griffin Creek.

RECENT ALLUVIUM

Recent alluvium borders the major rivers and forms bars and flood-plain deposits adjacent to present channels. The deposits are generally narrow and thin, and where cut banks expose the base, gravel and sand commonly overlie glacial drift and lacustrine silt.

IGNEOUS ROCKS

PRECAMBRIAN

Sills and dikes of diorite and gabbro and stocks ranging in composition from granitic to ultrabasic intrude the Belt Series (Precambrian) in Lincoln and Flathead Counties. Basic sills and dikes in northern Lincoln County were classified as hornblende gabbro by Daly (1912), in northern Idaho adjacent to the Montana-Idaho boundary as altered diabase and gabbro by Kirkham and Ellis (1926), in the Troy area as amphibolite or hornblende gabbro by Erdmann (1941), in the Libby quadrangle and adjacent areas as metadiorite by Gibson (1948), in Glacier Park and the Flathead region as metagabbro by Ross (1959), and in the Clark Fork quadrangle as quartz diorite by Harrison and Jobin (1963). Composition differs slightly, ranging between diorite and gabbro, from place to place in northwest Montana and northern Idaho. In this report, basic dikes and sills and stocks consisting predominantly of hornblende but containing minor pyroxene, feldspar, quartz, biotite, and accessory minerals are classed as metadiorite, as in Gibson's classification for similar igneous rocks in the Libby quadrangle.

METADIORITE DIKES, SILLS, AND STOCKS

Metadiorite sills, dikes, and stocks are dark-green-gray to dark-green and greenish-black crystalline fine- to medium-grained rocks, which show different degrees of alteration in different areas. Both equigranular and porphyritic types are present in Lincoln County, the equigranular type predominating. Sills mapped west of Yaak River within the Prichard Formation are the most numerous and can be traced the greatest distances along strike. The sills are discontinuous and range in thickness from a few feet to a thousand feet or even more, the average being between 100 and 200 feet. Dikes are generally narrower than the sills. A red soil develops over most metadiorite bodies as a result of the alteration of iron-bearing minerals to iron oxides.

Metadiorite dikes and sills are moderately abundant in western Lincoln County but are scarce elsewhere in the map area.

The Payne Creek stock in the Libby quadrangle is composed of an older metadiorite facies intruded by younger quartz monzonite. A small stocklike mass of metadiorite occurs southeast of Yaak Mountain adjacent to O'Brien Creek.

The metadiorite intrusive rocks are finely to coarsely granular bodies composed of hornblende, plagioclase, orthoclase, and orthopyroxene (hypersthene) as major constituents, and lesser amounts of carbonate, biotite, sericite, quartz, epidote, garnet, apatite, magnetite, sphene, rutile, ilmenite, leucoxene, tourmaline, zircon, and allanite. Megascopically, all the rocks are similar texturally and mineralogically. Even in thin section, few differences are noted.

Metadiorites commonly contain 40 to 70 percent hornblende and augite, 15 to 30 percent feldspar, less than 15 percent quartz, and 10 percent or less accessory minerals.

Hornblende ranges in grain size from 0.02 mm to 20 mm; average grain size is 1.4 mm. It is strongly pleochroic and most of it is green, blue green, or pale brown in plane polarized light. Some investigators (Calkins and MacDonald, 1909, Anderson, 1930, Gibson, 1948) interpreted the hornblende as of secondary origin through replacement of pyroxene. In thin section Gibson (1948, p. 21) and Dahlem (1959, p. 53) found horneblende replacing feldspar grains through envelopment and penetration, hornblende altering to chlorite, and hornblende to some extent altering to carbonate, epidote, and biotite.

Feldspar occurs in all these basic intrusive rocks. Weakly altered metadiorite sills contain as much as 30 percent plagioclase, most of which is oligoclase or andesine, whereas in more strongly altered sills the oligoclase or andesine is altered to albite or albite-oligoclase (Gibson, 1948, p. 23). Many basic dikes contain andesine; less common is sodic labradorite or oligoclase. Metadiorite stocks contain zoned feldspars of andesine and oligoclase. Dahlem (1959, p. 54) reported anorthoclase as a minor constituent in basic sills, most of it in sodic-plagioclase-rich sections. Only in basic dikes does soda-rich microcline and orthoclase become a major constituent. Dahlem also observed that sills intruding the Prichard Formation were sodic-plagioclase rich (albite to andesine) whereas sills intruding Wallace strata were zoned calcic-plagioclase rich (labradorite to bytownite). Feldspar ranges in grain size from 0.10 to 2 mm and averages about 0.60 mm, but some feldspar grains attain a length exceeding 30 mm. Feldspar commonly exhibits Carlsbad, albite, and pericline twinning, although some untwinned feldspar is present in these igneous rocks.

Fine- to medium-grained quartz is present in various amounts in the metadiorite bodies. Gibson (1948) thought that much of the quartz in sills was hydrothermally introduced, the sills reportedly containing as much as 12 percent quartz.

Accessory carbonate minerals (calcite or dolomite) are found in greater amounts in dikes than in sills and are secondary minerals. Magnetite is present in all metadiorite rocks as grains and crystals ranging in size from 0.05 to 0.4 mm. Biotite is common as fine-grained crystals or scaly aggregates about 0.05 mm in width, although some biotite crystals are as large as 0.2 mm. Zircon is common to abundant in sills as grains 0.02 mm or smaller. The chlorite mineral penninite is found in sills in fairly abundant amounts replacing hornblende and biotite, attesting to alteration of the sills. Dahlem (1959, p. 58) described other minerals in the sills as follows:

> "Allanite, apatite, pyrite, pyrrhotite, and chalcopyrite all occur sporadically as grains ranging from less than 0.005 mm to 0.5 mm. Apatite is quite abundant, appearing as euhedral crystals shot through all major constituents of the rocks. Allanite was rarely observed in thin section, and not confined to any particular mineral association."

In the Payne Creek stock, amphibolization of quartz diorite to metadiorite has occurred. Minerals contained in the intrusive rock are hornblende and plagioclase (andesine and oligoclase) and a few percent each of quartz and biotite. About 4 percent accessory minerals make up the rest. Interlocking hornblende crystals cut through quartz and andesine-oligoclase grains. Finely granular quartz is but little recrystallized.

Differences between mineral components in metadiorite bodies are few and do not offer conclusive criteria for distinguishing between sills, dikes, and stocks by study of thin sections alone. Orthoclase is slightly more abundant in some of the ferromagnesian-rich dikes, and amphibolization seems to be more pronounced in dikes.

Ross (1959) described as metagabbro sills and dikes some rocks in Glacier Park and the Flathead region that are texturally and mineralogically similar to rocks in western Lincoln

County that are classified as metadiorite. Metagabbro bodies consist principally of titaniferous augite, much of it altered to hornblende, and zoned plagioclase ranging in composition from An_{25} at the outer zones to An_{75} at the core. Quartz, apatite, and iron oxides are minor constituents. Alteration products include carbonate, sericite, and chlorite. According to Ross the original composition of the rock was closer to gabbro than diorite.

AGE

The age of these basic intrusive rocks is difficult to determine. Within the map area, they intrude all the Precambrian rocks except the Striped Peak and Libby Formations in Lincoln County. In the St. Regis-Superior area farther south, however, Campbell (1960) reported diabase sills and dikes cutting all formations except the unnamed feldspathic quartzite at Rock Rabbit Ridge (uppermost Missoula Group unit). He also reported dikes occupying faults younger than Middle Cambrian. In the Clark Fork quadrangle, Harrison and Jobin (1963) mapped altered quartz diorite sills that intrude the lower part of the Prichard Formation, and they mapped diabase dikes and sills that intrude Ravalli and Wallace rocks. They tentatively assigned the diorite to the Precambrian and the diabasic rocks to the Cretaceous, pending radiometric age determinations. Daly (1912), Schofield (1914a), and Gibson (1948) believed that the basic sills are Precambrian in age on the basis of their presumed equivalence to the Purcell Lava. These basic sills must have intruded Precambrian rocks prior to the Laramide orogeny, because they have been folded along with the sedimentary rocks. Some basic dikes may postdate folding that occurred during the orogenic movement that created the Northern Rocky Mountains.

MESOZOIC

GRANITIC STOCKS AND DIKES

Granitic stocks of quartz monzonite, granodiorite, and syenite-aplite crop out north and south of Libby and near Warland in Lincoln County. A few dikes in western Lincoln County range in composition from granite to diorite. The Dry Creek, Parmenter, Rainy Creek, and Warland stocks are aligned along a northeast trend, but the reason for the alignment is not apparent.

DRY CREEK STOCK

The Dry Creek stock, which has a surface area of 20.5 square miles, crops out northeast of Bull Lake (southwestern Lincoln County). The Bull Lake fault borders the west side of the intrusive mass. Mineralogically and texturally this granitic stock is similar to satellite stocks in Granite and Parmenter Creeks to the north and east and to the stock on Hayes Ridge southeast of the Dry Creek intrusive body.

Gibson (1948) described the intrusive body as consisting of massive very light gray medium-grained quartz monzonite, the dominant constituents being feldspar, quartz, and biotite. Andesine is the plagioclase feldspar, and orthoclase, some of it perthitic, is the dominant potash feldspar. Microcline is sparse in most places, but some thin sections show that it is locally abundant. Hornblende is present only near the borders of the stock and is sparse there. Apatite, zircon, and magnetite are uniformly distributed in thin sections; allanite is present but nowhere abundant. Sphene, tourmaline, and pyrite are scarce.

Quartz grains average 0.5 mm in diameter, but some coarser grained aggregates are 10 mm in diameter.

Euhedral and subhedral andesine exhibits zoning, zones commonly ranging from An_{40} to An_{30}. The grain size averages 0.9 mm; rare grains attain a maximum size of 5 mm.

Orthoclase has a wide range in grain size and abundance. The grains attain a maximum of 3 mm, and average about 1 mm in length. Most potash feldspar grains are fresh, but some replacement by sericite, epidote, and zoisite has occurred and is conspicuous in some sections. Most of the orthoclase and quartz are late in the sequence of crystallization, the two minerals forming a mosaic.

Gibson described strongly pleochroic biotite as the most abundant ferromagnesian mineral. Grain size averages 0.7 mm. The biotite is not greatly altered, but small parts of a few folia in most thin sections are partly replaced by chlorite, epidote, magnetite, or sericite, or by all of these minerals, together with a smaller quantity of leucoxene. Some of the magnetite occurs as irregular grains that seem to have crystallized late in the sequence; the mineral is commonly associated with epidote.

GRANITE CREEK STOCK

Adjacent to the eastern border of the Dry Creek stock is the Granite Creek stock, a small body of granodiorite that may be an apophysis of the larger body. Although it contains somewhat less orthoclase, the Granite Creek stock is mineralogically and texturally similar to the Dry Creek intrusive body.

A small granitic stock is reported to crop out on the north side of Ross Creek southwest of Mt.

Vernon. The reported occurrence was not verified by field examination.

HAYES RIDGE STOCK

A stock having a surface area of only half a square mile crops out on Hayes Ridge northwest of Bald Eagle Peak. The stock is composed of quartz monzonite and it is similar to the Dry Creek stock to the northwest. Gibson (1948) reported that the stock differs from the Dry Creek stock in that it contains 3 to 5 percent muscovite. The grain size differs from place to place, suggesting the presence of two rock types.

PARMENTER CREEK STOCK

Near the headwaters of the South Fork of Parmenter Creek is a small outcrop of intrusive rock identified by Gibson (1948) as the top of a stock. The rock is quartz monzonite, which is porphyritic in places. The porphyritic phase contains subhedral phenocrysts of plagioclase, orthoclase, and quartz 3 to 10 mm in diameter in a groundmass of the same minerals ranging from 0.1 to 0.5 mm.

BOBTAIL CREEK STOCK

The Bobtail Creek stock crops out on the east side of Bobtail Creek about 8 miles north of Libby, and forms bold rugged bluffs at its northern extremity. It probably extends westward under Quaternary glacial deposits in the valley of Bobtail Creek. Soil and tree cover obscure outcrops to the south. The surface area of the stock amounts to about 1.25 square miles.

Most of the rock is syenite containing large orthoclase phenocrysts that exhibit marked parallelism. A subordinate ferromagnesian facies is composed of pyroxene and amphibole, minor potash feldspar, and small amounts of magnetite and sphene. The ferromagnesian facies containing some vermiculite is exposed in a roadcut at the southwest margin of the stock; it is similar in composition to the pyroxenite in the Rainy Creek stock.

A typical specimen of syenite consists of euhedral orthoclase and sodic-calcic plagioclase (andesine) and contains a few percent each of pyroxene, amphibole, and quartz, the total making up about 92 percent of the rock. The other constituents are accessory minerals, which include apatite, magnetite, sphene, zircon, and pyrite. Small amounts of sericite, chlorite, epidote, allanite, zoisite, leucoxene, rutile, and iron oxides were identified (Gibson, 1948). Hornblende occurs in variable amounts; the greater part of it seems to be a hydrothermal alteration product of pyroxene (Gibson, 1948, p. 31).

Orthoclase phenocrysts attain a length of 9 cm but average about 1 cm. Most phenocrysts in the syenite facies show little alteration, but potash feldspar in the ferromagnesian facies shows weak to intense alteration to sericite and clay.

The composition of the andesine is An_{40}. It is a minor constituent in most specimens, but in some it makes up 35 percent of the rock, although it rarely exceeds orthoclase in abundance (Gibson, 1948, p. 30). It is equigranular, and the average length is less than 0.2 mm. It is zoned and shows Carlsbad, albite, and pericline twinning. Some of the plagioclase is altered to sericite and clay.

Pyroxene is anhedral to euhedral and the maximum length is 0.6 mm. Although most pyroxene observed in thin section was unaltered, Gibson (1948) described hornblende locally replacing pyroxene along cleavage planes, parting, and grain boundaries. Pyroxene is also replaced to a small extent by chlorite and epidote.

Hornblende is greenish black and its grain size ranges from 0.15 to 6.5 mm. Pleochroism ranges from yellow to yellowish green to dark green. In thin section, hornblende shows replacement by chlorite, biotite, or rutile.

Quartz is a minor constituent as interstitial grains in about 50 percent of the specimens.

The Bobtail Creek stock is intruded by light-colored dikelets and dikes (to 20 feet wide) composed of the same minerals as the stock but more equigranular and finer grained and in different proportions. Quartz may amount to as much as 11 percent of the rock. Gibson (1949) classified the dikes as quartz syenite and quartz monzonite.

Gibson (1949, p. 32) described feldspars, sphene, and magnetite as affected by deuteric action.

WARLAND STOCK

The Warland stock crops out on the north side of Warland Creek 1 mile northeast of Warland. The stock intrudes the Prichard Formation, and both the Prichard argillite and the intrusive rock weather to form gentle to moderate slopes. The stock is elliptical, and is believed to be fault controlled. It is composed of light-colored granulitic rock (alaskite); in hand specimen the rock is white, moderately altered, and porphyritic to equigranular. It is composed of feldspars, quartz, iron oxide, and accessory pyrite. Phenocrysts range to 30 mm and average about 5 mm. Feldspar shows weak kaolinitic alteration on exposed surfaces. Potash feldspar does not show a perferred orientation such as is characteristic of the Bobtail Creek stock.

Study of thin sections reveals that the most abundant minerals are microcline perthite (66 percent), subhedral oligoclase (15 percent), and quartz (18 percent); most of the other 1 percent is iron oxides. Grain size ranges from 0.05 to 5 mm. Most of the microcline is fresh and shows the characteristic grating structure. Plagioclase exhibits twinning according to the Carlsbad and albite laws. Quartz occurs as fine to medium anhedral grains interstitial to feldspars. Some biotite and accessory iron oxides and pyrite are present, as are traces of clinozoisite, zircon, muscovite, and chlorite. The rock is classified as porphyritic alaskite, but parts of the stock approach monzonite porphyry or quartz monzonite porphyry in composition.

A short inclined shaft on the Hoyt property cuts light-colored fine-grained rock composed of feldspar and quartz but containing some euhedral biotite, small crystals of hornblende, and accessory pyrite. The relationship of this rock to the surrounding alaskite is not clear, as contacts were not observed, but it is believed to be a vertical dike intrusive into and genetically related to the stock.

In thin section, the rock exposed in the incline is seen to be finer grained than that of the stock. The largest feldspar crystals are about 5 mm and the average is between 2 and 3 mm. Grain size of the groundmass is 0.1 to 1 mm. Constituent minerals include Carlsbad- and albite-twinned oligoclase, perthitic microcline exhibiting characteristic grating structure, some microcline showing no perthitic texture, quartz, some biotite, minor amounts of epidote and allanite (?), and traces of sphene, zircon, and pyrite. Interstitial very fine grained to microgranular quartz is more abundant than in the stock. The section examined contains about 31 percent plagioclase (oligoclase), 25 percent potash feldspar, 42 percent quartz, and 1 percent each of epidote and allanite (?). The rock is classified as fine-grained quartz monzonite.

OTHER STOCKS

A small stocklike body of syenite crops out 2 miles south of Poole Lake, but it is so obscured by soil and float that no detailed description is possible.

Strongly altered igneous float, possibly derived from a covered intrusive body, was observed south of Pine Prairie in the NE¼ sec. 22, T. 26 N., R. 24 W. The float is similar in composition to acidic volcanic rocks of the Hog Heaven district.

Float abundantly scattered over the surface north of Clark Mountain on the southeast side of the Kootenai River may be derived from a covered dike or stock of acid igneous rock. Megascopically the rock contains white feldspar phenocrysts 2 cm long in a medium-grained groundmass of red and white feldspars, muscovite, quartz, and biotite, listed in order of decreasing abundance. The feldspars and biotite are fresh; a few feldspar crystals show albite twinning. The rock was identified as porphyritic granite.

About 1½ miles up Copeland Creek, in the SW¼ sec. 5, T. 34 N., R. 30 W., is the Copeland adit (see description of Copeland property). The adit is believed to have intercepted an intrusive body, either a dike or stock, as prophyritic rock is scattered on the dump. The relationship of the igneous rock to the host rock (Prichard argillite) is unknown, as the intrusive rock does not crop out, and the adit is now inaccessible.

In hand specimen the porphyritic rock contains light-gray euhedral plagioclase megacrysts in a dark fine-grained micaceous groundmass. Plagioclase crystals range in length from about 4 to 15 mm and average about 8 mm. A few megacrysts attain a size of several centimeters. In some specimens feldspar makes up about 75 percent of the rock. Some feldspar crystals are embayed and irregular, suggesting resorption of crystal rims. Biotite and quartz and accessory pyrite occur in the fine-grained groundmass.

In thin section the most abundant minerals are identified as tabular subhedral sodic plagioclase (andesine), strongly pleochroic biotite, some sericite, and small amounts of very fine grained erratically distributed aggregates of anhedral quartz. Feldspar crystals in the matrix are about 0.4 mm in length. Other minerals identified include apatite, calcite, epidote, clinozoisite, and zircon. Sericite is present as aggregates, shreds, and patches on plagioclase; the sericite probably formed as a late hydrothermal mineral. Biotite is concentrated near the periphery of plagioclase crystals, sericite is in small plates, calcite forms irregular patches interstitial to biotite, epidote is small pale-green prisms, and apatite is subhedral prisms. Albite twinning is present in plagioclase crystals. The rock is classified as a diorite porphyry.

Although no vermiculite was identified in hand specimen or thin section, the covered intrusive body (if a stock) may contain a pyroxenite facies similar to that in the Rainy Creek stock and should be explored for vermiculite.

AGE

Granitic rocks and ferromagnesian facies of the stocks are assigned a late Mesozoic age based on the similarity of these igneous rocks to the granodiorite of the Nelson and Idaho batholiths. The Idaho batholith has been dated (Larson and others, 1958, p. 51) on the basis of lead-alpha determinations as about 108 million years old (early Late Cretaceous).

QUARTZ LATITE PORPHYRY AND DIORITE DIKES

Several quartz latite porphyry dikes north and southwest of the Rainy Creek intrusive are exposed for distances as great as half a mile, and they range in width from 50 to 75 feet. Specimens are characterized by light-gray to white phenocrysts in a dark-yellowish-green to brown or black groundmass, which weathers dark gray to rusty orange brown. The phenocrysts range from 3 to 25 mm in length; rectangular phenocrysts attain a width of 7 mm.

In thin section most of the phenocrysts can be identified as plagioclase, but a few are quartz. Feldspar phenocrysts exhibit Carlsbad, albite, and pericline twinning, and most are strongly sericitized. The most abundant feldspar is albite, which occurs in grains 0.35 to 0.7 mm in width and 1.0 to 2.35 mm in length. The very fine grained groundmass contains slightly more plagioclase than orthoclase; ferromagnesian minerals are also abundant, and iron oxides and moderately abundant quartz are disseminated throughout. Iron oxide grains (hematite and limonite) range from 0.10 to 0.42 mm; angular to subrounded quartz grains range from 0.05 to 0.43 mm.

Two diorite dikes south and southwest of the Rainy Creek pluton strike eastward (Beer, 1960). In surface exposure the rocks are light yellowish orange to light gray, are medium grained, and weather bright yellowish orange. Needles and grains of pyroxene are disseminated unevenly throughout the groundmass.

The most abundant mineral seen in thin sections is plagioclase; the grains range from 0.80 to 2.25 mm. Next most abundant are crystals and grains of pyroxene (probably diopside) ranging from 0.05 to 1.45 mm. Quartz is minor, and the grains range from 0.12 to 0.15 mm. Magnetite is also sparse; the grains range from 0.10 to slightly more than 2 mm.

AGE OF DIKES

Granitic dikes are closely related to acidic stocks, and it seems reasonable to assume that the ages of the two kinds of rock are similar, that is, late Mesozoic.

BASIC STOCKS

RAINY CREEK STOCK

The Rainy Creek stock is west of the Kootenai River about 8 miles northeast of Libby. This large complex stock of pyroxenite and syenite underlies part of the valley of Rainy Creek and extends east beneath Vermiculite Mountain. The irregular outcrop area of the stock is about 7½ square miles.

Aegirite pyroxenite and aegirite-diopside pyroxenite, syenite, and some pegmatite have intruded strata of the Wallace Formation. Pyroxenite is probably the oldest intrusive rock in the stock and constitutes about two-thirds of the stock. Almost all of the other one-third is syenite. Quartz veins containing small amounts of chalcopyrite, sphalerite, and galena are postsyenite in age, as they intrude pyroxenite and syenite. A small amount of opaline material associated with quartz veins was observed locally in the Zonolite Company's open pit. The border phase of the pyroxenite intrusive mass is rich in magnetite. An analysis of a magnetic concentrate of this material gave 63.80 percent iron, 0.60 percent titanium oxide, 2.40 percent silica, and 0.50 percent phosphorus.

Pyroxenite within the Zonolite pit is light-gray to yellowish-green coarse-grained friable rock composed of vermiculite, aegirite, aegirite-diopside, soft fibrous tremolite, apatite, magnetite, garnet, biotite, and hydrobiotite. Fluorine-rich apatite makes up 7 to 10 percent of the rock. Aegirite and aegirite-diopside both are locally vanadiferous. Boettcher (1963) described two major types of pyroxenite; the more abundant type (common pyroxenite) consists of pyroxene, vermiculite, and apatite. Another, finer grained type of pyroxenite consists of pyroxene and contains smaller proportions of vermiculite, apatite, garnet, magnetite, and sphene.

Near the center of the pyroxenite mass is a biotite-rich (biotitite) area consisting of 90 percent biotite, the rest being feldspar, pyrite, and calcite. Tremolite (amphibole asbestos) forms at the expense of pyroxenite in altered zones bordering syenite apophyses and quartz veins that cut the pyroxenite mass (Boettcher, 1963).

Aegirite-diopside and vermiculite crystals within the pyroxenite are as large as 4 cm. Some pale-green prismatic crystals of apatite are as much as 10 cm in length but average crystals are 1 or 2 cm long. The rest of the rock comprises about 5 percent orthoclase, less than 5 percent quartz, less than 1 percent plagioclase, and smaller amounts of sphene, carbonate, zircon, garnet, and biotite.

The southwestern part of the Rainy Creek stock consists of medium- and coarse-grained yellowish-green and gray syenite containing muscovite and iron oxides. Composition of the syenite is diverse; the main body is composed of potash feldspar and mica, whereas a small body of nepheline syenite southwest of the main syenite intrusive body is composed of nepheline, microcline, albite, and aegirine.

Most pegmatite bodies cutting the pyroxenite contain microcline as the most abundant mineral, but quartz, plagioclase, or pyroxene may predominate locally.

AGE

Time of intrusion of the Rainy Creek stock is believed to be late Crataceous or early Tertiary (Pardee and Larsen, 1929) or probably Middle Cretaceous (Boettcher, 1966).

TERTIARY

VOLCANIC INTRUSIVE AND EXTRUSIVE ROCKS

Tertiary igneous rocks in the southwest part of Flathead County are the host rock for silver-lead ore deposits, the most productive of which are the Flathead and West Flathead ore bodies near Sullivan Creek, about 10 miles west of Lake Mary Ronan.

The following descriptions of volcanic rocks in the Hog Heaven mining district and adjacent areas were written by W. D. Page (Johns and others, 1963, p. 32-39):

The igneous rocks have an areal extent of about 25 square miles [pl. 2], and consist of andesite and latite, andesitic tuff, and intrusive bodies of quartz latite, latite, andesite, 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 prevolcanic 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. 40] and the Sullivan Creek Spring drift.

The rocks have been named according to Johannsen's classification (1939) but were not delineated separately on Plate 2 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 (SW¼ sec. 9, SW¼ sec. 16, and cen. 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 change 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 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 mm. 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.

The biotite-hornblende andesite 1 mile southwest and 4 miles southeast of the Martin mine is a flow (or flows?). 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) described a similar structure in some of the plagioclase (oligoclase to andesine) from the Harkone volcanic rocks in Japan. He interpreted such feldspar as 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 pagioclase 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 and is exposed in a prospect pit 2 miles west of the Martin mine. The rock is generally altered but where fresh it is as Shenon and Taylor (1936, p. 9) described it:

> "The porphyritic latite . . . 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 cm to over 6 cm, 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 cm 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 tuff deposits are andesitic and are generally white to grayish-orange altered porous lightweight rock (for example, near Hubbart Reservoir, and east of Sullivan Creek Spring).

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 4 miles west of the Martin mine. 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 feldspar grains are angular and broken; the biotite is generally bent.

At least some of the tuff deposits are waterlaid. Altered crystal tuff of trachytic composition is well exposed in the Montana Sunset quarry east of Little Bitterroot River. It consists of hydrothermally banded 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.

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

Porphyritic quartz latite 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 matrix and 50 percent subhedral phenocrysts, 80 percent of which is plagioclase (andesine, Ab_{65}), 12 percent biotite, 8 percent rounded, resorbed quartz, and a trace of sanidine. The matrix is finely crystalline, granular, or saccharoidal in texture, and consists 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.

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 and southwest of Hubbart Reservoir and trend N. 46° W., but the eastern part of the eastern dike changes to a flow (?) containing numerous amygdules of quartz and probably zeolites. The basalt is strongly altered, the coarser grained calcic plagioclase and ferromagnesian minerals being completely replaced by epidote, chlorite, and magnetite. The less altered matrix, about 60 percent of the rock, consists of subparallel plagioclase (labradorite), also partly replaced by these minerals.

RELATIONSHIPS OF FLOWS AND HYPABYSSAL ROCKS

Most of the igneous 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. 40). 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. 41) also exposes a dikelike 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.

The contacts of a possibly intrusive body west of Brooks Creek (NW¼ sec. 15, T. 25 N., R. 24 W.) are not exposed, but thin sections show the rock to be coarser grained and of a composition (quartz latite) somewhat different from the other igneous rocks. Perhaps the rock is a plug or sill that has cooled slowly, resulting in a medium- to coarse-grained 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 Company underground maps show dikes and sills in deeper workings.

Some of the contacts between Ravalli beds and volcanic rocks are fault contacts that postdate solidification of the igneous rocks, thus obscuring the relationships. Sullivan Creek Spring mine shows the relationships best. The drift is in altered crystal-bearing 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 Hog Heaven area. Most igneous rocks are extrusive. The exact sequence of deposition of tuffs, flows, and hypabyssal rocks 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 deposition of a hot and gassy ash flow incorporating loose argillite pebbles from the old land surface and distributing 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; it overlies tuff at Battle Butte and overlies 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

The area investigated is within the Northern Rocky Mountain physiographic province, which fronts the Great Plains east of the Continental Divide. Through relief of diastrophic stresses that caused mountain building, collinear folds and subparallel faults were formed. Major fault trends are parallel or subparallel to folds, and strike between north and N. 35° W. In the southern part of the map area the structural trend is north, but it swings to northwestward in the Purcell Mountains and the northern part of the Salish Mountains. The strike of the Lewis overthrust along the eastern front of the Northern Rocky Mountains parallels the northwest trend of regional structure. Folding and faulting resulted in horizontal shortening and vertical thickening of sedimentary Belt rocks underlying Lincoln and Flathead Counties. Other results of structural deformation include joints, cleavage, and foliation.

FAULTS

North- to northwest-striking normal faults and moderate to high-angle overthrust and reverse faults illustrated by the Snowshoe, Leonia, Thompson Lakes, Pinkham, and Whitefish structures can be traced for many miles. Moderate to large displacements are characteristic of these longitudinal fractures. Long stretches of fault traces are straight, indicating the steep dip of the fault planes. Complex structures such as the Whitefish fault split into several branch faults, and the displacement diminishes to the northwest.

Most fault planes are not exposed, nor were they observed underground except in a few places. The Leonia fault has been intercepted underground at the Liberty mine, and the Savage Lake fault at the Crater prospect (Gibson, 1948). The Snowshoe fault is exposed in underground workings of the Snowshoe mine and at other properties. Several workings expose the Rock Lake fault in the southern Cabinet Mountains. West of the Rainy Creek road, brecciated rocks of the Thompson Lakes fault are exposed on the surface. Fault breccia of a west-northwest-striking fault was mapped east of Little Bitterroot Lake.

Gibson (1948, p. 40) described the west-northwest-striking Hope fault as later than north-striking faults in the region. The Shroder fault displaces the Thompson Lakes fault, and supports Gibson's observations that west-northwest structures displace north-striking structures.

East-striking structures are illustrated by the fault on the north side of Sheppard Creek, which has offset the northwest-trending Pinkham and Dunsire thrusts. Left lateral displacement of the northwest-trending thrust faults by the east-striking fault clearly illustrates that the east-striking fault is later.

A third group, northeast-striking faults, is illustrated by the Spar Lake fault (Pl. 1) and the Trail Creek fault, which is southeast of Lake Blaine (Pl. 2). The east- and northeast-striking faults may be contemporaneous, but such relationship has not been proved. In the Purcell Mountains some north-striking faults displace east-trending structures; this relationship may result from recurrent movement along older north-striking fault planes.

Little direct evidence of faults, such as breccia and gouge zones, was observed; most faults are covered, and structures were mapped on the basis of displaced contacts or beds, topographic expression, changes in stream pattern, drag folds, and alignment of springs. Many mapped structures are inferred without positive confirmation of their presence.

Many longitudinal faults are positioned near the crests and troughs of folds and displace fold limbs. Some of these faults, such as the Snowshoe fault, are important structures for localizing ore deposits.

Faults displace folds and are clearly later than folding. Some of the major faults, though, may have formed prior to Laramide diastrophism, some displacement taking place prior to folding.

Gibson (1948) observed at least three periods of movement along some faults in the Libby area, but did not recognize clear evidence of appreciable tilting of fault blocks, except possibly those related to the Bull Lake fault. Along mineral-bearing fault zones, renewed movement and renewed deposition of ore has taken place, and along some faults evidence is found for recent movement since the retreat of the Cordilleran ice.

The greater number of faults are mapped in the Purcell and Cabinet Mountains (Pl. 1) and the Whitefish Range (Pl. 2) where folding is complex. In the central part of the Salish Mountains and in the Mission, Swan, and Lewis and Clark Ranges, faults are not as numerous as in western Lincoln County. Most of the eastern faults are situated near the base of mountain ranges.

Throughout the map area, large-scale longitudinal faults, and to a lesser extent smaller transverse faults, have obscured fold relationships. Although displacement along longitudinal faults has occurred subsequent to folding, there is a possibility that the Leonia and Swan-Whitefish faults may have been active intermittently since Precambrian time.

Major faults are described as follows:

Leonia fault. — This high-angle upthrust was named the Leonia fault by Calkins and MacDonald (1909) and was also described by Kirkham and Ellis (1926), Gibson (1948), Erdmann (1941), and Johns (1959). It has been described by Kirkham (1930) as extending continuously from the Kootenai River near Cranbrook, British Columbia, through Boundary County, Idaho, to the Clark Fork River south of Bull Lake. Kirkham mapped its continuation in Canada as the Moyie fault, and described the stratigraphic displacement near Cranbrook (on Kootenai River) as 35,000 feet of Belt Series rock, including 10,000 feet of basic sills in the Aldridge-Prichard and Creston-Ravalli Formations and an unknown thickness of Purcell Lava in the Siyeh-Wallace Formation.

Gibson traced the fault north of Bull Lake continuously for 10 miles, and it is probably much longer. In the Liberty mine, the gouge and breccia zone is 20 feet wide and the attitude is vertical. Gibson (1948, p. 41) stated:

> "There is no evidence to indicate the movement along the fault is other than vertical. Its downthrow is on the east, and in the northwest part of the [Libby] quadrangle it brings the upper part of the Wallace Formation in contact with the lower part of the Prichard, all of the Ravalli Formation being cut out. The displacement there is at least 26,000 feet."

Gibson mapped the southward extension of the Leonia fault beneath glacial deposits and alluvium and beneath Bull Lake to terminate opposite Ross Creek. The fault exposed in the Trio prospect west of Bull Lake was described as a possible split of the Leonia fault, or less probably a segment of the Leonia structure. Kirkham connected the Leonia fault with the Bull Lake fault, but this interpretation was believed by Gibson to be incorrect.

From Brush Creek north to the point where the Kootenai River enters Idaho, the Leonia fault strikes N. 25° to 35° W., and dips vertically or very steeply to the west. Surface expression along this distance of 10 miles is poor, and several swamps occupy this trend. The fault is believed to be cut by northeast-trending faults in the Star Creek area, and displaced by an east-trending fault 1 mile north of Ruby Creek. Metadiorite bodies closely parallel the fault on the west side. Where the Leonia fault crosses the Kootenai River, Wallace strata east of the fault strike N. 30° W. and dip 80° SW, whereas Prichard strata west of the fault strike N. 35° W. and dip 65° to 75° NE. In most places the fault follows the strike of the beds, although in some localities it intersects bedding at a slight angle. Apparent vertical displacement of the Leonia fault in the Star Creek-Ruby Creek area is believed to be through 32,000 feet of Belt, including basic sills and dikes. Horizontal displacement was not determined.

Bull Lake fault.—Calkins and MacDonald (1909) observed this fault in two places and named the structure the Bull Lake fault. Gibson (1948, p. 42) described it as a normal fault, younger beds being exposed in the downthrown block (west side). The fault dips 45° to 60° W. and is traced for 13 miles along a curving course, described as concave toward the east (Pl. 1).

Gibson (1948) stated that there is good evidence that in an earlier period in its history, the fault was a thrust, but the present relations of Striped Peak strata west of the fault and Wallace strata east of the fault indicate that it is now a normal structure. Where the fault crosses the Dry Creek and Payne Creek intrusive bodies, quartz monzonite in the footwall and Belt rocks in the hanging wall are brecciated. Foliation, which is parallel to the fault plane, increases in intensity in the quartz monzonite as the fault is approached. To the north, sedimentary rocks on the east side of the fault are crumpled and schistose. The fault zone is 200 feet wide at one place, and south of Payne Creek it attains a width of ¾ mile. Calkins and MacDonald (1909) observed that such foliation and shearing were not likely to have been produced by normal faulting of a fissure dipping 45 degrees.

South of Crowell Creek the footwall of the fault forms a scarp 60 feet high, separating for a short distance quartz monzonite from glacial material. Gibson (1948) attributed the scarp to recent renewed fault movement but did not discount differential erosion as the possible cause.

Farther southeast on the lower end of a ridge west of Ibex Peak, the fault zone is 150 feet wide and contains abundant barren quartz. Adjacent strata are closely folded and in part metamorphosed to quartz-mica schist. In the Mount Berray vicinity, abundant vein quartz and the contorted bedding in the Wallace Formation are believed to mark the position of the fault. North of the East Fork of Bull River, the fault seems to cut a small metadiorite sill, and farther south the fault is lost in Wallace strata, which are neither sheared nor strongly folded.

Gibson (1948, p. 43) could find no evidence that the Moyie-Leonia thrust connected with the Bull Lake fault and extended south to the Clark Fork River as proposed by Kirkham. He cited evidence that movement on the Leonia fault is down on the east side, whereas the Bull Lake fault is downthrown on the west side.

O'Brien Creek fault.—The abrupt rise of the mountain front facing O'Brien Creek north of Kootenai River suggested the fault that Gibson (1948) named the O'Brien Creek fault. Gibson traced the fault from Savage Lake north beyond Lynx Creek, using topographic and stratigraphic evidence to estimate its position. The fault is normal, has steep west dip, and is downthrown on the west side.

About 1 mile north of Savage Lake, the fault passes through a narrow zone of sheared and strongly folded strata, and along the Kootenai River the Wallace strata are closely folded, crumpled, and sheared.

Northwest of Lynx Creek the fault is concealed beneath glacial deposits, but it is believed to pass through or adjacent to a metadiorite outcrop at the Rankin prospect, to continue over Yaak Mountain, and to parallel the east side of Pine Creek valley to the Idaho boundary. The fault strikes N. 30° W. and parallels the strike of Ravalli and Wallace sedimentary rocks.

Evidence for the occurrence of the fault north of Kootenai River is a zone of sheared and crumpled Wallace strata on each side of a depression near the summit of Yaak Mountain, a sheared zone several hundred feet wide containing gouge and breccia where the fault crosses Yaak River in Wallace strata, faceted ridges along the east mountain front facing Pine Creek valley, and the alignment of Pine Creek and O'Brien Creek valleys, which suggests that faulting may in part determine the valley position and trend. A basic igneous dike is associated either with the fault or with a sheared zone adjacent to the fault at the Black Diamond mine. A topographic depression 2 miles north of the Black Diamond property suggests the position and northward trend of the fault.

Savage Lake fault.—Gibson (1948) described the Savage Lake fault south of the Kootenai River as a structure inferred partly on physiographic evidence and partly on structural evidence. He observed the fault at one place—the Crater Lake prospect, where it strikes north, is vertical, and is downthrown on the west side. The fault zone is 40 feet wide, and a persistent metadiorite dike follows the fault.

Erdmann (1941, p. 14) mapped the extension of Savage Lake fault across the Kootenai River 1 mile west of Koot Creek. Pardee (Gibson, 1948) attributed Kootenai Falls to uplift along the east side of the Savage Lake fault, which he thought must be near the entrance to the gorge.

From Kootenai River north to Lynx Creek, surface expression of the fault is poor, and its position is inferred. Between Lynx and O'Brien Creeks the fault is marked by broken and crumpled Wallace strata, gouge, and broken zones, which are exposed in road cuts, and by drag folding along the valley occupied by Kilbrennan Lake.

The fault (or a branch) crosses Yaak River 2½ miles below Yaak Falls, and in a road cut on the north side of Yaak River road, two segments of the fault zone 12 and 15 feet wide are separated by an 8-foot basic dike. The segments strike N. 30° W., dip 45° SW., and parallel the strike of Ravalli rocks. The dike obviously intruded the fault zone. Both dike and fault zone contain quartz veinlets and abundant iron oxides. Small northeast-striking shears and post-dike slips cross the fault. Drag folding marks the fault position north of Fourth of July Creek, but beyond that point the structure disappears in undisturbed Prichard strata.

A fault segment connecting the Savage and O'Brien Lake faults was mapped south of O'Brien Creek.

Snowshoe fault.—This fault was named by Calkins and MacDonald (1909) for the Snowshoe mine, and was traced by Gibson (1948) for a distance of 16 miles—from Elephant Peak north to Horse Creek. Two mineral-bearing shear zones at the Glacier Silver-Lead property may be the continuation of the Snowshoe fault north of Horse Creek. Gibson mapped a west-northwest-striking fault in Horse Creek, and this fault is believed to displace the Snowshoe structure eastward (right lateral movement). The subsidiary parallel fault and the Snowshoe fault at the Silver Mountain Group (Gibson 1948, p. 113), may correlate with the two shear zones at the Glacier Silver-Lead property, and the anticline just east of the Glacier Silver-Lead workings may represent a displaced segment of the Snowshoe anticline.

The crush zone of the Snowshoe fault, striking north or slightly east or west of north, ranges in thickness from 2 to 12 feet. Where observed underground, fault dips range from 65° to near vertical, flatter east dips being recorded south of the Snowshoe mine. The topographically higher west side is downthrown with respect to the east side. In No Creek an inferred fault with right lateral movement probably displaces the Snowshoe fault, and north of Bear Creek a near-parallel segment has been displaced a short distance north by the Snowshoe fault, possibly by late recurrent movement.

The north-plunging Snowshoe anticline is displaced along the crest by the Snowshoe fault and is truncated along its south end by the Rock Lake fault.

The Snowshoe mine and several other properties are located along the fault. Production of lead, zinc, copper, and precious metals from veins within the fault zone is recorded from some of the properties described in this report under "Description of Mining Properties, Lincoln County, Libby District."

Rock Lake fault.—Paralleling the Lincoln-Sanders County line is the Rock Lake fault named by Gibson (1948) and extending from near Wanless Lake to Dad Peak on a bearing of N. 35° W., a distance of 13 miles. Between Wanless and Rock Lakes, the structure cuts the Ravalli Formation but for most of the rest of its length the east and west blocks are respectively the Wallace and Ravalli Formations. In three exposures described by Gibson the fault plane is vertical, and movement is irregular in amount and direction but is dominantly vertical. Downthrow is on the east side for most of its length except where the Snowshoe anticline is truncated. Here, near Flattop Mountain, upthrow is on the east side (Gibson, 1948, p. 46). Vertical displacement is reported to be abount 2,500 feet near St. Paul Lake.

A fault in the West Fork, a tributary of Vermilion River, is mapped on the basis of topographic evidence and drag folding. The fault parallels the trend of Prichard strata and disappears beneath Quaternary glacial deposits in lower West Fork valley. An east-striking vein at the Snowfall property is believed to be displaced by the fault, but because the adit east of the fault was inaccessible the underground occurrence of the structure was not confirmed. The West Fork fault may be the southeast continuation of the Rock Lake fault.

Quartz Creek fault.—The Quartz Creek fault strikes northwest to north and extends from Libby Creek valley to Indian Peak, a distance of more than 20 miles. The fault plane was not observed but the overturned limb of the Striped Peak Formation east of the fault is displaced south. Near the headwaters of Quartz Creek, the horizontal component of displacement is believed to be several thousand feet.

The fault probably strikes southeast beneath alluvium in the valley of Libby Creek, continuing southeast of Libby toward the Swamp Creek depression, or, on crossing Kootenai River, follows the mountain front south beneath glacial deposits. Pardee (Gibson, 1948, p. 63), on physiographic evidence, suggested a fault south of Libby where a straight, well-defined front occurs. Because of the difficulty of accounting for the great amount of excavation in the valley to the east, Pardee suggested relative depression by a strike fault parallel (or nearly so) with bedding trending beneath Quaternary glacial deposits.

Poole Lake fault.—The Poole Lake fault strikes N. 20° W. and is believed to dip steeply east. It extends for a distance of at least 11½ miles, from Doak Creek north to Flatiron Mountain. At one exposure a 20-foot fractured zone of clay gouge and shattered rock contains abundant limonite and a few quartz veinlets. Southeast of Flatiron Mountain the position of the fault is marked by a basic dike. The fault may join the Thompson Lakes fault at its southern extremity.

The fault parallels the strike of Wallace sedimentary rock or has truncated both the formation and fold axes at small to medium angles. No conclusive evidence was found that would permit determination of amount and direction of movement. Drag folds occur in the east block adjacent to the structure.

A near-parallel fault striking north to northeast cuts the Bobtail syenite stock and trends northwestward across Pipe Creek divide, passing west of Reynolds Lake. This fault dips east and is displaced by the Poole Lake structure west of Poole Lake. The fault is exposed in a roadbank north of Reynolds Lake where the plane dips 55° E. Fold axes are displaced near Poole Lake, and bedding in the west block adjacent to the fault is drag folded. North of Poole Lake the block between the Poole Lake and Bobtail Creek faults is believed to be a graben.

Thompson Lakes fault.—One of the major faults mapped in western Lincoln County is the high-angle Thompson Lakes fault, which extends from Big Rock Creek (southeast corner of Pl. 1) northwest to the International Boundary, a distance exceeding 75 miles. The fault strikes northwestward, and follows the trace of the axial planes of the Kootenai anticline and Yaak River syncline throughout a large part of its strike length. North of Beulah Creek the fault is inferred. At the International Boundary a basic igneous sill is mapped west of the fault. The west (downthrown) block shows drag folding adjacent to the fault, and linear-trending saddles and valleys mark the position of the fault.

One exposure of the fault zone west of Rainy Creek road (Beer, 1960) reveals a 10-foot brecciated zone crosscutting Wallace sedimentary rocks, here striking northeastward. The fault is restricted to the Wallace Formation except in the McKillop Creek area, where on the nose of the Kootenai anticline, Striped Peak strata are displaced.

To the southeast (southwest corner of Pl. 2) the Thompson Lakes fault probably merges with the Rainy Creek fault to continue south along the eastern side of the Thompson River valley. It is displaced to the east by the Shroder Creek fault. East of Thompson River in a logging road cut south of Big Rock Creek, a zone of breccia and altered limestone 50 feet thick is exposed. Elsewhere along Thompson River, the fault is expressed as a linear faultline scarp prominent on aerial photographs. Stratigraphic displacement here is believed to be about 1,000 feet.

Rainy Creek fault.—The high-angle to vertical Rainy Creek fault approximately parallels the axis of the Rainy Creek syncline north to northwest from the Shroder Creek-Rock Creek area to merge (?) with a subsidiary structure west of Parsnip Mountain. The trace of the fault plane extends for about 60 miles, in part following the trace of the axial plane of the Rainy Creek syncline. The Rainy Creek pyroxenite-syenite intrusive body obscures the fault in Rainy Creek and its tributaries. The east fault block seemingly moved down about 500 feet relative to the west block.

Transverse faults in Wolf Creek (right lateral) and Barron Creek (left lateral) displaced the Rainy Creek fault. Vertical and east-dipping joints paralleling the fault are recorded in the east fault block. In the Wolf Creek area, parallel quartz veinlets occur adjacent to the trace of the fault and fold axis.

Pinkham thrust.—The Pinkham thrust is a medium- to high-angle west-dipping upthrust fault, the west block having moved up. It is described as the Brush Pass thrust by Hall (1962) and as the Elk Mountain thrust by Galster (personal communication) and others of the U. S. Army Corps of Engineers who reported intercepting the structure while core drilling in the vicinity of the Great Northern tunnel through the divide separating Fortine Creek and Wolf Creek. The thrust has been mapped from Little Bitterroot Lake past Elk Mountain and across the Kootenai River near Rexford; it may continue north to the International Boundary, a distance exceeding 70 miles. The fault trends N. 20° to 30° W., paralleling Belt strata or truncating them at slight angles in most places but at nearly right angles north of Davis Mountain and a few other localities.

The fault was first recognized (Johns, 1961) on Edna Creek divide, between Pinkham Creek and Edna Creek, where Prichard and lower Piegan Group strata (P_1) are in fault contact. Here, Ravalli Group strata are cut out, indicating vertical displacement amounting to about 7,000 feet. North and south of Edna Creek divide the displacement decreases to 3,500 feet. Southeast of Little Bitterroot Lake the fault splits into several "horsetailing" fractures. These smaller faults dip to the north or northeast.

The Pinkham fault (Pl. 2) follows the axis of the Bitterroot Lake anticline, but in the Brush Creek-Sheppard Creek area it swings east of the axis, cutting the east limb of the fold on the highest part of the anticline.

Drag folding, brecciation, silicification, shearing and jointing in adjacent rocks, and fracture cleavage were recorded at various localities in and adjacent to the fault zone. West of Sylvia Lake, Ravalli strata are tightly folded—a local feature resulting from fault drag. Much brecciation and shattering were observed along Griffin Creek north of Little Bitterroot Lake.

The thrust is displaced (left lateral movement) by east- and northeast-striking transverse faults.

Dunsire thrust.—The name Dunsire thrust (Pl. 2) was proposed by Hall (1962, p. 42) for a high-angle upthrust fault mapped from a point north of Ashley Lake, thence northwestward of Ashley Mountain and Ingalls Mountain, to terminate before reaching Fortine Creek, a distance of 28 miles. The fault is nearly parallel to the Pinkham thrust but lies 2 miles east of it.

A thrust fault of lesser magnitude than the Pinkham thrust, the Dunsire thrust is characterized by fractured rocks and irregularly dipping blocks of strata. Beds west of the fault dip vertically and those east of the fault are near horizontal. Siyeh rocks are exposed on both sides of the fault, and exact displacement could not be calculated. Hall reported the apparent stratigraphic throw in the Basin Creek area as between 500 and 1,000 feet.

North of Swamp Creek (Pl. 1) is a northwest-striking structure paralleling the Pinkham thrust but situated ½ to 1 mile east of it. This fault is in the same relative position to the Pinkham thrust as is the Dunsire thrust in the Griffin Creek area but relative movement is reversed, as here the west side is down and the east side has moved up.

Mission fault.—Clapp (1932, p. 24) named the Mission fault for its occurrence along the west base of the Mission Range and classified it as a steeply dipping longitudinal thrust fault. The Mission fault is a major tectonic break forming the east side of the western branch of the Rocky Mountain Trench (Pl. 2). The fault extends north to Bigfork where it disappears beneath Recent alluvium; the concealed fault continues north to merge with, displace, or be cut by the Swan fault, possibly in the vicinity of Lake Blaine.

Evidence for the fault is the stratigraphic relationship between east-dipping Piegan units on the west shore of Flathead Lake, which, if projected eastward, would underlie Appekunny (older) beds. At Yellow Bay an outcrop of Siyeh limestone (molar-tooth limestone containing pyrite) lies west of the inferred fault position, whereas strata in the lower Ravalli Group crop out east of the fault. The fault is believed to be a high-angle west-dipping normal fault. Stratigraphic displacement amounts to at least 4,500 feet but probably does not exceed 10,000 feet. The entire Grinnell and lower Piegan unit (P_1) plus an undetermined amount of upper Appekunny and lower Siyeh beds have been offset by the structure.

Pardee (1950, p. 395) described the southeastward extension of the Mission fault to St. Mary's Lake in Lake County and cited evidence for its position along the east side of Mission Valley. Pardee, on physiographic evidence, determined the throw on the fault near St. Ignatius to be 8,000 feet or more and dated the movement as late Tertiary or early Quaternay.

Nobles (1952, p. 25) described the trace of the Mission fault along the base of the Mission Range as buried beneath alluvium and glacial deposits for the greater part of its length. Using 10,000 feet as the thickness of Siyeh limestone and reconstructing minor folding, Nobles estimated net slip on the Mission fault in the Finley Point-Blue Bay region (south of Yellow Bay) to be 14,000 feet and displacement progressively less farther north.

Swan-Whitefish fault.—Along the west base of the Swan Range is the Swan fault, named by Clapp (1932). Northwest of Lake Blaine the Swan fault is believed to continue beneath Recent alluvium and Quaternary gravels in Flathead Valley following the eastern border of the Rocky Mountain Trench to the International Boundary. The Whitefish fault described by Pardee (1950, p. 394) is believed to be equivalent to the Swan fault (Johns and others, 1963, p. 41) and the Deep Creek fault and branch faults (Smith, 1963, p. 125) along the east border of the Rocky Mountain Trench fronting the Whitefish Range.

Clapp described the Swan fault as a longitudinal east-dipping fracture on which the east block was thrust upward. Pardee indicated on a structural section that the Whitefish fault dips west, the west block being dropped relative to the east block.

In Swan Valley, Page (Johns, 1964) mapped longitudinal faults east and west of Swan Lake. Along the west shore a high-angle normal(?) fault has a stratigraphic throw amounting to about 2,000 feet. The eastern border fault has a greater but undetermined displacement. This fault is a normal fault, the west block downthrown. Along Sixmile Creek northeast of Swan Lake, Grinnell rocks west of the fault are in contact with older Appekunny rocks east of the fault. A mile farther southeast, horizontal Piegan strata (P_1) are in fault contact with Grinnell beds.

Along the east border of the Rocky Mountain Trench in the Stillwater Valley, Smith and Barnes (Johns and others, 1963, p. 41) described the Swan fault as a master fault entering the Whitefish Lake area from the south along the valley of Whitefish Creek and splitting 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 1 mile northwest of Upper Whitefish Lake, where it too splits. The stratigraphic throw on the fault is of the order of 11,000 feet near Upper Whitefish Lake.

Smith (1963, p. 125) described the Whitefish fault (Deep Creek and Trench Boundary faults) in the northern Whitefish Range as follows:

> "The stratigraphic displacement on the Deep Creek fault is about 3,000 feet along Deep Creek. To the southeast, branch faults increase this figure by 2,000 to 3,000 feet in the Fitzsimmons Creek area. To the north the fault forms the eastern wall of the Rocky Mountain Trench. The displacement on the minor branch fault southwest of Mount Barnaby is about 2,500 feet. At the International Boundary the displacement on the western branch (faulting Devonian limestone against the Kintla Formation) is estimated at 10,000 feet; on the eastern branch, shown by field evidence in the Fernie map area, west half (Leech, 1960), where the Kintla is faulted against the Siyeh Formation, displacement is estimated at 2,500 feet. The total displacement is therefore 12,500 feet . . .
>
> "South of the map area [southern Whitefish Range] the Deep Creek fault follows the West Fork of Whitefish Creek and joins the

fault complex, extending through the center of Whitefish Range. This complex lies on the northern prolongation of the Swan fault, which forms the western boundary of the Swan Range. The Deep Creek fault is the only fault of this complex to continue throughout the map area with undiminished displacement. Thus, in the sense that the two are continuous, the fault that forms the eastern wall of the Rocky Mountain Trench is the Swan fault."

Smith described that part of the Rocky Mountain Trench adjacent to the northern Whitefish Range as an asymmetric north-northwest-trending zone of normal faulting, and on all faults observed in the trench, west blocks are believed to have been downthrown and rotated to the east. In the trench area adjacent to the northern Whitefish Range there is no evidence of strike slip movement, and no faults were mapped crosscutting the trench.

Stryker fault.—Gilmour (1964) described the principal normal fault in the Stryker area as extending from glacial deposits in the southeast (Olney area) to glacial deposits in the northwest (east of Dicky Lake). In this report it is named the Stryker fault after Stryker Lake, as the fault passes adjacent to the east shore of the lake. The fault trace trends N. 35° W. and is easily seen on aerial photographs.

Ravalli rocks in the east block have been faulted against lower Piegan strata (P_1) to the west, the west block having moved down. Displacement along the fault decreases to the northwest. East of Stryker Lake the fault coincides with the eastern boundary of the Rocky Mountain Trench. Here the stratigraphic throw was determined by Gilmour to be about 4,000 feet.

Another longitudinal normal fault trends northwest from upper Lazy Creek, splitting into two branches at Herrig Mountain, the west branch continuing past Fitzsimmons Creek to join the Whitefish (Deep Creek) fault at Deep Creek. The west block moved down relative to the east block.

To the southeast the Stryker and the adjacent eastern structure are believed to continue through the outcrop area bounded by Stillwater River and Whitefish Lake. Two normal faults mapped in this area are in the Siyeh Formation; their west sides dropped relative to the east sides.

Flathead-Tuchuck fault.—The Flathead fault, named by Clapp (1932) for its position along the west base of the Flathead Range, was described as a steep, east-dipping longitudinal upthrust structure of late Cretaceous or early Tertiary age. The hanging wall (east side) was thrust upward. The Tuchuck fault, the probable northwest continuation of the Flathead fault along the east side of the Whitefish Range, was named by Barnes (1963, p. 77).

Erdmann (1944, p. 79) described the Flathead fault as extending from Belton Point (West Glacier) southeast for a distance of 110 miles in which the effects of the fault can be recognized. He described the fault plane as dipping 75° NE, movement being upward on the east (hanging wall) block of the fault. Stratigraphic displacement is great, ranging between 5,000 and 15,000 feet.

Ross (1959, p. 88) described the fault from north to south as follows:

> "Another great fault of northwesterly trend extends from McGees Meadow (northwest of West Glacier) past the lower end of Lake McDonald, down the upper part of the valley of Emery Creek, between Firefighter Mountain and the Flathead Range, and thence along the northeast side of the valley of the South Fork of the Flathead River (to Twin Creek) . . . The dip appears to be southwest, and the rocks now west of the fault are higher stratigraphically than those east of it. If the dip was definitely known, these relationships would prove that the fault was normal and of great vertical displacement with the down-dropped block on the South Fork side. However, the dip has not been thus established because the fault surface is hidden under Cenozoic materials and vegetation . . . Pardee (1950, p. 398-399, pl. 1, sec. B-B') agrees that the fault northwest [northeast] of the South Fork is normal, but he does not draw it the full length of the valley."

Deiss (Pl. 3) mapped a major fault in the valley of the South Fork trending about N. 20° W., portions of which are concealed by alluvium and drift. The fault trace from the Flathead County line north to Spotted Bear River follows the base of the west flank of the Flathead Range. Topographic expression is apparent where the fault trace crosses near-perpendicular ridges and in a swale between Blackbear Creek and Mid Creek.

Between Blackbear Guard Station and Meadow Creek Cabin the fault splits into two segments enclosing a body of Devonian strata in fault contact with Cambrian on the west and units of the Missoula Group on the east. The fault is believed to be a high-angle structure whose west side moved down relative to the east side. From the county line north to Blackbear, the stratigraphic throw is large, as strata in the lower part of the Missoula Group (mapped as Miller Peak by Deiss) are in fault contact with upper Middle Cambrian beds. The stratigraphic displacement decreases northward. Ross (1959, Pl. 2) mapped the structure from Twin Creek north to a point near Halfmoon Lake, projected under Tertiary and Quaternary deposits.

At Riverside Creek the Flathead fault is displaced eastward by right lateral movement on a northeast fracture, and near the mouth of Spotted Bear River it is displaced farther southeast by right lateral movement on a west-northwest-trending fault.

To the north, Barnes (1963, p. 77) described the Tuchuck fault as a normal fault extending from the valley of Wigwam River, north of the International Boundary, south to the Middle Fork Flathead River where it seemingly joins the Flathead fault along the western side of the Flathead Range. Barnes stated that the displacement along the fault shows considerable lateral variation, but he believed the total separation to be about 9,000 feet. Where the fault crosses Coal Creek the stratigraphic separation exceeds 10,000 feet.

Lewis overthrust.—Named by Bailey Willis (1902), the famous Lewis thrust fault and the fractures coextensive with it extend for a total exposed length of more than 300 miles. In Glacier National Park, Ross (1959, p. 76) described the average strike as N. 30° W., and the dip as southwest at generally less than 10 degrees, although in a few places the dip may be as much as 20° W. In the Flathead region the overthrust strikes N. 30° W. and dips as much as 50° SW.

In the map area (Pl. 3), Ross (1959, p. 76, 78) described the Lewis overthrust as follows:

> "The Lewis overthrust . . . is, in a broad way, a single continuous fracture, but in detail there are many departures from this simple picture . . . In the vicinity of Schafer Meadows in the southern part of the Flathead region, two thrusts are mapped. One, interpreted as the main Lewis overthrust, passes around the east side of Lodgepole Mountain and continues southward along the valley of the Middle Fork of the Flathead. The other, apparently much shorter . . . continues up Roaring Creek and past Argosy Mountain . . .
>
> "In Glacier National Park the Flathead region and areas just south of the latter, the rocks immediately above the Lewis overthrust belong to the Belt Series . . . whereas farther south they are at higher horizons and Paleozoic rocks are present short distances west of the thrust trace . . . The rocks beneath the thrust in Glacier Park are largely of Late Cretaceous age, whereas much of the rock in corresponding position to the north and south is Paleozoic."

In Deiss' map area, the Lewis overthrust was traced for a distance of 4 miles. Here the overthrust trends about north-south, and Missoula units override Kootenai (Cretaceous) sedimentary rocks.

Barron Creek fault.—In this report the east-striking transverse structure in Barron and Warland Creeks (Pl. 1) is described as the Barron Creek fault. The fault extends west from upper Warland Creek to Pipe Creek, a distance of 24 miles. In Warland Creek the fracture strikes east, changing trend to N. 80° W. in Barron Creek. In Pipe Creek it merges with the northwest fracture cutting the Bobtail Creek syenite stock, then extends past Pipe Creek divide, to die out northwest of Reynolds Lake.

Movement on the Barron Creek fault is believed to be vertical, the north block having dropped relative to the south block. The structure displaces fold axes, sedimentary rock contacts, and a longitudinal fault. The Barron Creek fault may have exerted structural control on the emplacement of the Warland stock at the mouth of Warland Creek.

Some strike-slip movement in the valley of Warland Creek is indicated by right lateral movement on axial-plane fold traces. To the west in Barron Creek the displacement is believed to be dip-slip movement, the direction of offset on sedimentary units and planar structures being determined by their amount and direction of dip.

Shroder fault.—A large high-angle transverse strike-slip fault near Shroder Creek (Pl. 2) is named the Shroder Creek fault (Page, 1963). The fault trends slightly north of west over much of its strike length. It 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 faultline scarp, but eastward it changes direction and for 13 miles is expressed by linear creeks and low divides. Page (Johns and others, 1963, p. 47) reported the movement as dominantly strike-slip, the north side having moved east and down with respect to the south side, as the north-south fault east of Thompson River is offset about 1½ miles, and the Wallace-Ravalli contact is offset about 2 miles.

Elk Divide fault.—Hall (1962, p. 43) described the major transverse fault in the Sheppard Creek-Brush Creek area (Pl. 2) and named it the Elk Divide fault for its intersection with that topographic feature near the head of Brush Creek. The fault trends about N. 85° W. and has an approximate length of 15 miles. Near Wolf Creek to the west the axial-plane traces of two southward-plunging folds are believed to end abruptly at the fault trace, suggesting that the fault ends a short distance west of Wolf Creek. On the basis of the configuration of the fault trace and attitude of associated shears, Hall interpreted the fault as nearly vertical. Sedimentary contacts, longitudinal fault traces, and fold axial traces have been displaced left-laterally along the strike of the fault. Left-lateral separation is approximately ½ mile where the fault cuts the Elk Mountain anticline, and to the east the separation is approximately ¼ mile in the vicinity of the Ravalli-Piegan contact and the Ingalls syncline. Drag folding adjacent to the structure at Elk Divide is associated with the fault. It was not determined whether the Prichard-Ravalli contact is displaced (Hall, 1962, p. 44).

Ashley Mountain fault.—The Ashley Mountain fault is an east- to northeast-striking fault having near-vertical dip, as indicated by its trend across topography. It extends from Grubb Mountain to Lost Creek (Pl. 2), a distance of about 17 miles. Movement seems to be dominantly dip slip, the south block being upthrown relative to the north block. Displacement amounts to 500 to 1,000 feet. The fault offsets fold axes and the green-gray argillite marker bed (p€rl) in the Ravalli Formation.

FOLDS

Folds consist of tight to broad symmetrical, asymmetrical, and overturned structures. The fold on Vermilion River is completely overturned, but elsewhere only the east limbs are overturned. Folds plunge north or south, and double-plunging folds are present. Axial-plane traces of folds strike northwest to north paralleling the strike of Belt strata and local lower Paleozoic sedimentary rocks. Traces of axial planes have been mapped for distances exceeding 40 miles, but most folds are continuous only for much shorter distances. A breached anticline occurs west of Flathead Lake between Ronan Creek and Dayton Creek (Pl. 2). A recumbent fold involves the Prichard Formation (Pl. 1, sec. C-C'), and an overturned isoclinal syncline is illustrated at Raven Creek and Crystal Creek (Pl. 1).

Broad to tightly compressed and shallow to deeply folded strata are characteristic of the western third of the map area (Pl. 1). Depths of most folds in this region range from 1½ to 4 miles, but some reach depths of 6 miles. Distances between crests and troughs of these folds range from 1½ to 10 miles; one distance of 16 miles is exceptional.

In the central and eastern parts of the map area (Pl. 2 and 3), the folds are broad and open and are characterized by gentle dips, decreasing depths, and long distances between crests of folds. In western Lincoln County, compressive forces produced tight folds, whereas farther east the compressive forces were in part relieved by movement along the Lewis overthrust, and folding was broader and less complex. Major folds in the map area are described as follows:

Sylvanite anticline.—The Sylvanite anticline, in the Purcell Mountains, trends northwest and is continuous in Lincoln County for a distance of 26 miles. It is symmetrical, plunges southeast, and extends from Kedzie Creek northwestward to the Bonner County, Idaho, line (Pl. 1). Prichard strata are exposed in the core of the fold, and Ravalli strata are exposed on the limbs.

The Sylvanite mining district, on the crest of the fold, has produced native gold, and the Mathews talc deposit is near the southeast end of the structure.

Poole Lake syncline.—The Poole Lake syncline extends from the head of McMillan Creek northwest to a point west of Poole Lake, a distance of 22 miles. The structure is a symmetrical to asymmetrical fold in Wallace strata, dip of the west limb being locally steeper than that of the east limb. The trace of the axial plane trends through the center of the Bobtail Creek stock and is displaced by the Poole Lake fault. A small outcrop area of Striped Peak sedimentary rock is exposed in the trough of the fold 6 miles southeast of Libby.

Yaak River syncline.—The Yaak River syncline is a southeast-plunging symmetrical fold mapped from the headwaters of Bull Creek, a tributary of Bobtail Creek, north to the International Boundary. The axial-plane trace of the fold extends for 37 miles and parallels the South Fork Yaak River for some distance. Along the South Fork, the west limb has been faulted. The south end of the fold is displaced by a fault. The syncline, mapped near the center of a belt of Wallace strata, parallels the Kootenai anticline. Northwest-striking joints dipping 67° W. occur locally.

Kootenai anticline.—The Kootenai anticline, which is slightly asymmetrical, extends for 40 miles. The axial-plane trace has been mapped from Snell Creek, a tributary of the Fisher River, to Pink Mountain. Ravalli and Wallace strata dip somewhat more steeply in the east limb than in the west. Both limbs of the fold are locally displaced by a fault that follows the axial plane closely but not precisely. The trace of the axial plane is displaced (left lateral movement) by a fault in Barron Creek. West-dipping axial-plane cleavage and east-striking vertical joints were observed in the vicinity of Pink Mountain.

North Fork anticline.—The North Fork anticline is symmetrical and trends and plunges northwest. It extends for 22 miles, from the headwaters of the South Fork Big Creek to the International Boundary. The fold axis parallels the strike of upper Prichard rocks and is confined within a narrow outcropping belt of Prichard strata. East-striking vertical or south-dipping joints occur adjacent to the crest of the fold.

Rainy Creek syncline.—The Rainy Creek syncline extends for a distance of 30 miles, from McKillop Creek north to Barron Creek. The axial plane is displaced by east- and northwest-striking faults, and is intruded by the Rainy Creek stock. The fold is double plunging and slightly asymmetrical. Moderately dipping east and west limbs are parallel to the strike of Wallace and Striped Peak strata.

Snowshoe anticline.—The Snowshoe anticline can be traced from Wanless Lake north beyond Libby, a distance exceeding 30 miles. Its trend and plunge are north. Along strike the fold is broken at its crest by the Snowshoe fault, which closely parallels the trace of the axial plane of the Snowshoe anticline throughout its strike length, and the south end of the anticline is displaced by the Rock Lake fault. The trace of the axis of the Snowshoe anticline is believed to have been displaced eastward (right lateral) by a fault in Horse Creek.

Spar Lake syncline.—The Spar Lake syncline is a discontinuous north-plunging symmetrical syncline in Prichard, Ravalli, and Wallace strata, which is believed to extend north from Ross Creek to Star Creek, a distance of 30 miles. Beyond Star Creek the syncline is believed to be broken by the parallel-trending Leonia fault. Gibson (1948, p. 40) described that part of the fold along the western border of the map area as part of a large persistent syncline trending northwestward and which was mapped by Anderson south of the Clark Fork River, where it is offset by the Hope fault.

Fairview anticline.—The Fairview anticline (Pl. 1 and 2) is a broad, open southeast-plunging fold, the east limb slightly steeper than the west. It extends northwestward from a point near Lynch Lake (upper Pleasant Valley Fisher River) to the headwaters of Swamp Creek, a distance of 32 miles. South of Lynch Lake and near its northern terminus the fold is covered by Quaternary glacial deposits.

The structure is expressed in Prichard argillite at the surface. Along strike it is displaced by longitudinal and transverse faults. The Boulder Hill, Kirkpatrick, and Strodtbeck deposits are situated near the crest of the fold.

Elk Mountain anticline.—The asymmetrical double-plunging Elk Mountain anticline extends for a distance of 42 miles—from 3 miles northwest of the Flathead mine to 5 miles north of Davis Mountain. The east limb is overturned. At several localities the anticline is displaced by longitudinal and transverse faults (both left- and right-lateral movement). The fold is expressed in the Ravalli Formation, and to a lesser extent in the Prichard where erosion or faulting has exposed the upper few hundred feet of that unit.

Ingalls syncline.—The Ingalls syncline was named by Hall (1962) for Ingalls Mountain in the Pleasant Valley-Star Meadow area. The east limb of the Elk Mountain anticline becomes the west limb of the Ingalls syncline; the east limb of the syncline dips 10 to 20°. The fold trends N 25° W. and plunges gently northward. It extends northwestward from a point north of Ashley Lake to Beaver Creek, a distance of 30 miles. The trace of the axial plane is displaced westward about 1,300 feet on the north side of the east-trending Elk Divide fault.

Mount Creek syncline.—The Mount Creek syncline extends from the headwaters of Mount Creek northward for 28 miles to Lost Creek, south of Tally Lake (Pl. 2). The structure is a broad open syncline. Along strike the fold is displaced by several faults.

Silvertip syncline.—The Silvertip syncline (Pl. 3) was first described by Chapman (1900), who commented on the rapid change in bedding attitudes at certain localities on each side of the axial plane.

The fold can be traced in the map area for a distance of 28 miles, from the Flathead-Powell County line (southeast corner Pl. 3) to the headwaters of Whitcomb Creek. About 4 miles north of Spotted Bear River the syncline has been cut by a west-northwest fault.

The syncline is a broad, open symmetrical fold. The east and west limbs consist of rocks of the Missoula Group (Precambrian), whereas Middle Cambrian, Devonian, and Mississippian strata occupy the trough.

FRACTURE CLEAVAGE

Moderate- to well-developed and intense fracture cleavage is present in part of the map area where it commonly is best developed in argillaceous beds of Piegan strata. Where incompetent beds of argillitic rocks are situated between competent quartzite beds, well-developed cleavage is characteristic.

Fracture cleavage is parallel or nearly parallel to axial planes of folds (axial-plane cleavage) and parallel or subparallel to longitudinal thrust or normal faults and strike-slip faults. The two types of cleavage are genetically related to folding and later faulting.

Hall (1962) described well-developed cleavage in strata along the east flank of the Elk Mountain anticline. Cleavage, localized on the steep limb of the fold, seemingly resulted from slippage of beds through intense shearing produced by folding. The cleavage parallels the axial planes of the adjacent anticline and syncline and the high-angle Pinkham thrust.

Fracture cleavage is well developed adjacent to the Pinkham thrust south of Rexford and on the limbs of the Kootenai anticline. Intense fracture cleavage nearly obliterating bedding was mapped in argillaceous Ravalli strata along a northwest-trending ridgeline 2 miles southwest of Lake Mary Ronan. This particular fracture cleavage may be genetically related to the intrusive (?) effect of parts of the Tertiary igneous mass cropping out a few miles west of the ridge.

Fracture cleavage is predominantly oriented in a strike direction from north to N. 40° W. Dips range from vertical to moderate or steep northeast or southwest dips. A subsidiary set strikes N. 30° to 45° E. and has steep northwest and southeast dips, and another strikes N. 60° to 70° W. and has steep dips to the south.

JOINTS

Jointing is pronounced in Beltian strata of the map area; strong and persistent joint sets show evidence of some displacement. Two dominant and two subsidiary sets of joints were observed in the west and central parts of the map area. The major joint set strikes N. 70° W. to west and is vertical or dips at steep angles to the north or south. The second set strikes north, and is vertical or dips west. Of the two subsidiary sets, one strikes N. 30° to 40° E. and has nearly vertical dips, and the other strikes N. 20° to 45° W. and is vertical.

Northwest of Troy in the area around the confluence of Yaak and Kootenai Rivers, Dahlem (1959) plotted 200 joints at 60 different outcrops. In this area two joint trends were discernible. The dominant set strikes N. 8° E. and dips west at moderate angles; the other strikes N. 45° W. and most of the dips are vertical, although some joints dip steeply northeast.

The weaker northwest set is parallel to strike of the oldest major fault system but opposite in dip. The dominant trend may have developed along a shear direction from northwest faulting (Dahlem, 1952, p. 91).

In the upper Wolf Creek-Sheppard Creek-Griffin Creek area, Hall (1962) described the most prominent joint set in all rock units as striking N. 85° W. and dipping nearly vertical. A second set, striking N. 30° E., is also nearly vertical, and where encountered these joints are well developed, but joints of the northeast set are not as abundant as those of the west-northwest set.

Erdmann (1944, p. 91) described two sets of master joints in the Hungry Horse Reservoir damsite area, one striking N. 67° to 80° E. and dipping 60° to 75° S., the other striking N. 40° to 45° W. and dipping 51° to 63° W. Two minor sets strike N. 20° to 30° W. and N. 35° to 45° E. The joint sets are in Siyeh Limestone.

Master joints are strong, clean, and persistent, and there is some evidence of movement along joint planes. Joints are closely spaced in thin irregularly bedded limestone but much wider spaced in thick-bedded to massive limestone.

Along the west flank of the Mission Range, Nobles (1952) described large-scale block jointing showing two major trends. One set strikes north and is vertical, and the other set strikes N. 80° E. and dips 81° N.

SUMMARY OF STRUCTURE

Structural elements in Lincoln and Flathead Counties include large tight to open symmetrical and asymmetrical folds trending northwest or north and a few short northeast-striking folds at the head of Quartz Creek. East of Thompson River, bedding attitudes suggest a broad west-plunging syncline upon which northwest folds are superimposed; such a structure may have resulted from warping previous to Laramide diastrophism, possibly as early as late Precambrian time.

Major faulting postdates folding and closely parallels the trace of fold axes. Northeast- and east-striking faults displace north and northwest normal and high-angle thrust (reverse) faults. West-northwest-striking faults displace north-striking structures.

The dominant feature is the northwest-trending Rocky Mountain Trench. This topographic form is both a graben and half graben; vertical displacement must be measured in thousands of feet. The Swan and Whitefish faults, paralleling the eastern side of the trench, perhaps exert the greater influence on the trend of the topographic feature.

Many writers assign folding of the Belt Series to the late Cretaceous-early Tertiary Laramide orogeny. Some faulting is perhaps related to Laramide time, but undoubtedly major faulting has also occurred during the Tertiary period. Faulting in the Whitefish Range took place while the Kishenehn Formation (late Eocene-early Oligocene) was being deposited. The Lewis overthrust is late Eocene or early Oligocene and the upper plate has been cut by north-trending block faults having sporadic movement throughout the Tertiary and Pleistocene (Mansfield, 1923, p. 269).

The emplacement of volcanic rocks in the Niarada area postdates major movement on north-trending faults; 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 fault is unknown. The volcanic rocks themselves are cut by faults probably related to intrusion of a stock at depth or to recurrent movement on pre-existing faults (Johns and others, 1963, p. 48).

AGE OF FOLDS AND FAULTS

Structural deformation is believed to have taken place in British Columbia and northern Idaho from Precambrian to Recent, the earliest diastrophism occurring in late Precambrian and the latest during the Cenozoic period. Leech and Wanless (1962) described a late Precambrian orogenic event occurring in southeastern British Columbia between 700 and 800 m.y. ago. Evidence is based on Precambrian granitic intrusions and metamorphism of Precambrian rocks, inferred Precambrian northwest-trending folds being accentuated during the Laramide orogeny. Reid and Greenwood (1968) described two ages of Precambrian deformation and metamorphism in the St. Joe area of northern Idaho. The earliest folding (west-northwest) and metamorphism is correlated with the Coeur d'Alene metamorphism dated about 1,200 m.y. ago. The second period of folding (northwest) and metamorphism is correlated with diabase intrusive rock dated at 669 m.y., the igneous rock being injected and metamorphosed late during the second period of deformation. Three other periods of deformation are described for the St. Joe area, the first postulated as a Nevadan age because of K-A dating on hornblende of 172 m.y., and the other two of probable early Tertiary age.

Ross (1959, p. 75) postulated diastrophic events during the Paleozoic era in Glacier National Park and adjacent regions, absence of certain formations suggesting widespread uplift and concomitant gentle and broad crustal movements. The regional flexures were not, however, of continental scope. Similar diastrophic movements, according to Ross, took place in Mesozoic time, as indicated by the absence of sedimentation after Mississippian time until deposition of Ellis (Jurassic) sedimentary rocks, which suggests that downwarp occurred late in the Jurassic period.

During very late Cretaceous time, gentle uplift of the region commenced, culminating during the early Tertiary in intense folding, faulting, and rapid uplift, the diastrophic event named the Laramide orogeny. The latest period of deformation, a continuation of Laramide crustal movements, took place in the late Cenozoic period when block faulting occurred (Pardee, 1950). Minor crustal movements and readjustments have continued into the present.

In Lincoln and Flathead Counties, no direct evidence for a period of Precambrian diastrophism was found, although indirect evidence suggests that such an event or events did occur. Ross (1959, p. 75) described the Purcell Lava and related metagabbro intrusive bodies as probably following tension fractures during emplacement produced by mild diastrophic disturbances. Northwest-trending faults of large displacement, illustrated by the Leonia, Mission, Swan, and Whitefish faults, are believed to have had a long complex history and may have originated during the Precambrian era. The Rocky Mountain Trench, bounded on the east by the Swan and Whitefish faults, constitutes a boundary between two distinct lithologies in the Ravalli Group, the Appekunny-Grinnell rocks east of the trench and the Ravalli Group undifferentiated west of the trench. It is postulated that uplift through faulting during Precambrian time along the eastern flank of the trench subjected the Appekunny-Grinnell rocks to subareal erosion, while Ravalli rocks west of the trench were being deposited in an offshore environment. This may account for the lack of oxidized iron minerals and increased thickness of the Ravalli Group west of the trench.

East and west of Hubbart Reservoir, in southwestern Flathead County, attitudes of Ravalli rocks suggest Laramide northwest-trending folds superimposed on an earlier (Precambrian?) broad gentle west-plunging flexure. Some Tertiary intrusive rocks in the Hog Heaven district were emplaced along the synclinal axis of this flexure, a potential structural zone of weakness.

Lincoln and Flathead Counties offer no direct evidence of diastrophic events during the Paleozoic and Mesozoic eras nor evidence the Laramide orogeny closed the Cretaceous period. Erosion in Lincoln County has removed any Paleozoic and Mesozoic strata deposited, except in a folded and fault-bounded block in which Middle Cambrian rocks are exposed in the valley of Swamp Creek, south of Libby. The youngest strata in Flathead County are Lower Cretaceous rocks (Kootenai Formation) mapped by Ross (1959, p. 65) along the Continental Divide in eastern Flathead County. Because these Kootenai rocks were involved in Laramide folding, the age of this diastrophic event is later than early Cretaceous, but earlier than Kishenehn rocks (late Eocene to early Oligocene) in the valley of the Flathead River (North Fork), which were tilted by subsequent faulting but which were not folded.

ORE DEPOSITS

GENERAL FEATURES

Mesothermal and epithermal mineral deposits have yielded silver, lead, gold, zinc, copper, and tungsten in eight mining districts within the area mapped. Moderate amounts of placer gold have been obtained from the Libby and Troy districts and from less-productive bars along the Yaak River, Kootenai River south of Rexford, and Wolf Creek, all in Lincoln County. A bog-manganese deposit is present in the Hog Heaven mining district. Barite deposits occur in three widely separated localities. A large deposit of vermiculite and a body of impure talc are present in western Lincoln County.

HISTORY AND PRODUCTION

Schrader (1911) reported that the first mining activity on Libby Creek took place in 1867, but hostile Indians killed several of the prospectors, and placer mining was temporarily abandoned there. In the early eighties prospectors from the Coeur d'Alene district entered the Libby area and worked on Libby Creek near the junction with Poorman Creek.

According to Schrader (1911) and Gibson (1948), some of the earliest placer gold was obtained from the Libby placer on Howard Creek; another important producer was the Vaughan and Greenwell placer of the Eldorado group, situated above the Libby placer on Howard Creek. Howard and Leigh Creeks were named for early locators of placer claims, and Shaughnessy Creek for one of the earliest locators of a quartz lode. Other placers were located on Cherry Creek, Little Cherry Creek, Callahan Creek, and West Fisher Creek.

In 1887 one of the early deep mines in the Libby district, the Silver Mountain, was located on Granite Creek by George Blackwell and associates. The Silver Butte (later King) mine in the Silver Butte district was located about the same time at the head of Silver Butte Creek, a tributary of East Fisher Creek. In October 1889, J. Abbot and A. F. Dunlap staked three claims on the south slope of Snowshoe Creek, where they developed the Snowshoe mine, which became one of the two major producers in western Lincoln County. Gibson (1948) reported that the mine produced 130,000 tons of lead-silver-gold ore, for which net smelter returns amounted to $1,086,000.

Calkins and MacDonald (1909) reported that both the Snowstorm (formerly B and B) and Big Eight mines, on Callahan Creek, Troy district, had shipped ore prior to 1905, and that the Sylvanite properties were idle at this time but had formerly produced free-milling gold ore. The Snowstorm mine became the major producer in the area, and Gibson (1948, p. 68) credited the property with lead, zinc, silver, and gold production amounting to $4 million. Ore reserves were estimated by Gibson (1948, p. 47) at 207,000 tons. A 500-ton custom mill, which treated ore from the property and from other mines in adjoining districts, was destroyed by fire in 1927; the property has since been virtually inactive.

During the 1890's gold-quartz lodes were discovered near the head of West Fisher Creek and its tributaries. Important producers were the American Kootenai, Fisher Creek (formerly Branagan), and Jumbo group (formerly Tip Top) properties, which yielded oxidized ore from veins paralleling bedding. The Midas and Gloria (formerly Little Annie) mines produced later, the Midas yielding some tungsten during World War I.

Other properties valuable for lead-zinc-silver ores were located along and adjacent to the Snowshoe fault.

In 1890 copper was found in eastern Flathead County. In 1896 prospectors rushed into the area east of the Continental Divide when the government acquired this ground from the Blackfeet Indians and opened it for mineral location, but the deposits did not prove to be commercial. The area is now included in Glacier National Park.

Prospecting for lodes and placers was carried on along the South Fork Flathead River and its tributaries during this period (early nineties). Several copper-bearing quartz lodes were located on tributaries of Logan, Felix, and Hoke Creeks and some development done. These veins proved to be narrow and noncommercial. According to rumor, placer mining was done on Willow Creek, now named Danaher Creek, an upper tributary of the South Fork Flathead River south of Big Prairie in the Ovando quadrangle, date unknown.

In the Star Meadow area the West Virginia property was located prior to 1900 by John Sullivan. The Foolsberg and Blacktail mines were first developed in 1920 and 1936 respectively. Total mineral production has been small.

Ore was discovered in the Hog Heaven mining district of Flathead County in 1913. Development work by The Anaconda Company was suspended when the vein pinched out, but during 1928, lessees drifting north discovered the Flathead ore. The Ole mine and other properties in the vicinity were then located. The Flathead mine continued production until 1946. In the period 1959-64, lessees operating the West Flathead mine shipped ore to the Anaconda smelter. Total value of production of silver, lead, gold, zinc, and copper from the district amounts to $6 million or more.

PLACERS

Placer deposits have produced significant but not large amounts of gold. They were most actively worked for a 30-year period after their discovery in the early eighties. Revival of activity during the depression accounted for increased placer production for about 6 years. Since 1935 placer mining has been sporadic, the most recent activity being in 1964 on ground along Cherry Creek owned by Mr. Bolyard of Libby. There a small dam and a pipeline were constructed to provide sufficient head for hydraulicking cemented gravel of glacial or glaciofluvial origin.

Early placer mining was confined to stream gravels along Libby, Howard, and Cherry Creeks where the gold from glacial till or from gravel in pre-existing stream channels was reconcentrated in or along present stream channels to permit profitable operations. Schrader (1911) stated that for 20 years or more (1890 to about 1910) placer production had been derived chiefly from the glacial till. The gold produced in the district between 1902 and 1909 amounted to $52,178, almost the entire amount coming from the Libby Placer Company property and the Vaughan-Greenwell placer mine.

The deposits are described as seemingly confined to the valleys and low places. Ground on higher slopes and benches contains insufficient placer gold to constitute workable ground.

Schrader (1911, p. 72) described the gold as mostly coarse nuggets; pieces that he examined ranged in size from a pea to the end of a man's finger. Most of the gold was deep yellow and from 0.926 to 0.945 fine. Gibson (1948) described the placer gold as shades of yellow to rusty red, some particles having a trace of quartz adhering to the grains.

During the summer of 1934, hydraulicking was in progress at the Libby Creek Gold Mining Company property and Red Gulch placer, both on Libby Creek. During the period 1929-32, the Nugget placer and the Harry Howard placer, the latter on Cherry Creek below the mouth of Smearl Creek, were active.

Other placers on the Yaak River and its tributaries (Snipetown and Solo Joe), Copeland placer on Copeland Creek, placers along the Kootenai River near Ural (Pioner placer) and below Rexford, the Miller placer on West Fisher Creek, the Tideman placer on Wolf Creek, and the Ajax placer on Vermilion River, were active during the 1930's, but production from most of these operations was not significant.

Production of gold from placers in Lincoln County from 1906 to 1964 amounted to about 2,388 ounces of gold and 72 ounces of silver, valued at approximately $58,000. Placering in the Libby Creek drainage was active until 1947 and again in 1964.

NONMETALLICS

Nonmetallic minerals other than vermiculite have accounted for only a small portion of total mineral production in the area. The Rainy Creek deposit was discovered about 1915, the vermiculite first being recognized by E. N. Alley of Libby during World War I while he was checking for the presence of vanadium in a tunnel penetrating the Rainy Creek stock. The Zonolite Company was formed and development of the vermiculite body commenced in 1923; small-scale mining began in 1925 from open cuts. The Minerals Yearbook lists some production of vermiculite from the stock for 1926 and 1929, and in 1930 value of vermiculite produced from the district amounted to $25,000. Production figures for later years are restricted.

In 1936 the Vermiculite and Asbestos Company employed 35 men and was constructing an all-steel mill. Vermiculite was mined from an open cut 100 feet long. The Zonolite Company at this time was shipping pit-run ore from the higher grade sections of the ore body.

In 1939 the Vermiculite and Asbestos Company and the Zonolite Company, through a merger, became the Universal Zonolite Insulation Company. Since 1948 the company has operated as the Zonolite Company, now a division of the W. R. Grace Company. In 1964 the Zonolite pit produced 2,400 tons of ore per day, from which the mill produced about 500 tons of concentrates.

Barite production amounting to several hundred tons was obtained from a barite vein 2 miles south of Loon Lake. The deposit was discovered by Gerald Kenelty in the early 1960's.

CLASSIFICATION

Ore deposits in the eight mining districts are classified as lodes and gold placers. The lode deposits are classified according to the metals contained in the ore.

LODES

Lodes are classified as gold-quartz veins, tungsten-quartz veins, silver-lead-zinc deposits, silver-lead replacement deposits, copper-bearing quartz veins, and manganese deposits. Silver-lead-zinc deposits contain appreciable amounts of zinc and occur as both fissure fillings and replacement bodies. In most of these deposits, lead minerals are more abundant than silver minerals, and gold and copper are sufficiently abundant to make their recovery profitable. Silver-lead deposits are dominantly of the replacement type and contain only insignificant amounts of zinc. These two types of deposits account for most of the production in the map area, although production from gold-quartz veins has been significant. Production of tungsten has been negligible, and manganese has not been found in commercial quantity.

DISTRIBUTION

Most gold-quartz veins in the Libby area are near the head of West Fisher Creek and adjacent to two of its tributaries, Bramlet Creek and Standard Creek. Another property, the Herbert prospect, is on Prospect Creek in the northern Libby district.

Other properties chiefly valuable for gold are the Sylvanite properties near Crawford Creek and the Black Diamond mine on Pine Creek in the Yaak River area, gold-quartz veins in a syenite stock east of Warland, and the gold-quartz veins at the Viking mine near the head of Silver Butte Creek.

A quartz vein containing traces of gold and silver crops out on Herrig Creek, and quartz veinlets containing very small amounts of gold are present in the Haskill Pass area.

A scheelite-quartz vein at the Waylett group (formerly Moose Hill) property on Miller Creek contains a minor amount of gold. A small amount of scheelite has been produced from the Midas vein on Standard Creek in the West Fisher district, a few miles west of Miller Creek. Scheelite is present at the Big Sky Property in the Libby area.

Silver-lead-zinc veins in the Libby district are located along the Snowshoe fault; near Callahan Creek and on Grouse Mountain in the Troy district; at the head of Silver Butte Creek in the West Fisher district; and at other scattered prospects throughout central and northeast Lincoln County.

Silver-lead replacement deposits are represented by ore bodies in the Hog Heaven district on tributaries of Sullivan Creek north of Niarada. These deposits are small to medium irregular high-grade epithermal lodes.

Copper-bearing quartz veins in the Libby and Troy districts are situated near Copper Mountain, near Stanley Peak and Mount Vernon, and on Cedar Creek west of Libby. Quartz veins containing scattered copper sulfides and oxides are sparsely distributed in the Yaak River district and Thompson Lakes, Whitefish, and Kalispell areas. Copper in quartz veins is most abundant in the Star Meadow district of the Pleasant Valley area and near Ksanka and Poorman Mountains east of Eureka. Copper minerals occur sporadically at scattered prospects east of Hungry Horse Reservoir. Near Swan Lake, veinlets of malachite were observed.

Noncommercial manganese is associated with quartz veins near Caribou Creek in northern Lincoln County, and a bog-type manganese deposit occurs in the Hog Heaven district.

MINERALOGY

Gold-quartz veins contain at least 90 percent milky white massive quartz where not stained by iron oxides. Vugs are rare, and native gold is commonly associated with sulfide minerals.

Native gold forms irregular masses and small elongate particles in quartz. Veins more than a foot wide have produced the richest ore, and adjacent wall rock may locally contain enough disseminated gold particles in sheeted quartz veins to make low-grade ore. Coarse visible native gold has been reported from ores mined at the Tip Top, Midas, Fisher Creek, and Gloria (formerly Golden West) mines.

Sulfide minerals most abundantly associated with gold are pyrite, galena, sphalerite, and pyrrhotite. Small amounts of chalcopyrite, arsenopyrite, and tetrahedrite are present in the gold-bearing veins. The carbonate minerals calcite, dolomite, and siderite are sparse. Sericite is a common gangue mineral, and some chlorite and epidote are probably derived through alteration of the wall rock. Gibson (1948) reported the sequence of deposition of the sulfides as pyrrhotite, pyrite, and sphalerite, followed by galena and chalcopyrite. In some ores, native gold replaces sphalerite or is deposited along boundaries between sphalerite, pyrite, pyrrhotite, or galena. Gold and sulfides replace both smaller brecciated quartz grains and larger solid quartz grains. Quartz is the earliest mineral in the depositional sequence, and a second generation of quartz was deposited after the gold.

Quartz grains range from 0.005 mm to 17 mm and average about 1 mm in diameter. Quartz grains show interlocking relationships.

The average tenor of the ore at the Gloria was reported (personal communication, Paul Lewis) to have been 8 ounces a ton, high-grade specimens assaying as much as 32 ounces a ton.

At the Midas mine, scheelite occurs with quartz, carbonate minerals, and native gold. It is possible that the tungsten-bearing quartz veins should not be classified separately but rather should be included as a modified type tungsten-bearing gold-quartz veins. The classification used herein is predicated on the kind of minerals contained, however, and the Waylett ore contains only trace amounts of native gold without appreciable sulfides.

Other occurrences of scheelite are noted in descriptions of individual mines. Scheelite is present in massive white quartz veins and sheared zones as white blebs and masses fluorescing white or blue white under shortwave ultraviolet light. Scheelite and quartz were the only minerals identified, although a small amount of a gray copper-bearing mineral, tentatively identified as tetrahedrite, occurs in a few pits. Assays of veins and sheared zones exposed in pits range from 0.22 to 3.72 percent WO_3 (tungsten trioxide).

Silver-lead-zinc veins contain a varied mineral assemblage, the predominant sulfide minerals being argentiferous galena, pyrite, and sphalerite in a gangue of quartz, calcite, and sericite. Sphalerite is not as widespread as galena. Pyrrhotite, arsenopyrite, magnetite, tetrahedrite, chalcopyrite, and scheelite are subordinate in amount to the other ore minerals in most deposits, but at about 15 percent of the properties in the Libby district, pyrrhotite and arsenopyrite are the dominant sulfides in silver-lead-zinc veins. Silver and native gold are present in sufficient amounts to make their recovery profitable. Some copper carbonates and oxides are present in the oxidized portions of the veins.

Gangue minerals other than quartz, calcite, and sericite include ankerite, biotite, chlorite, actinolite, garnet, and iron oxides.

Silver-lead replacement deposits are characterized by the presence of both primary and secondary ore minerals. Primary sulfides in order of abundance are pyrite, galena, and antimonial matildite (silver-bismuth sulfide), subordinate enargite, bornite, tetrahedrite, and minor sphalerite. Native gold is present in trace amounts to several ounces a ton (Ole mine), and native silver was reported at the Flathead mine (Shenon and Taylor, 1936). Near the surface, where supergene enrichment has been extensive, secondary sulfides are argentite, marcasite, and covellite. Sulfate oxidation products are ubiquitous yellow beudantite (a clay mineral containing an arsenate or phosphate and sulfate of ferric iron, lead, and bismuth), and anglesite, siderotile, melanterite, and malachite. Gangue minerals are quartz, barite, iron oxides, alunite, jarosite, and clay. Iron-rich beidellite (a clay mineral similar to kaolinite) is present in solution holes or tubes and is locally referred to as "fumarole mud".

The sequence of deposition of minerals at the Flathead mine, probably representative for the district, is listed by Shenon and Taylor (1936) as a stage of fine-grained quartz and pyrite, fracturing, and a second stage of very fine grained quartz, barite, and sulfides. Galena followed barite, and matildite probably was contemporaneous with galena as it is intimately intergrown with it.

Mineralogy of copper-bearing quartz veins is relatively simple; most of the ore minerals are the common copper-bearing sulfides. In order of abundance the sulfide minerals are pyrite, chalcopyrite, bornite, chalcocite, and a very subordinate amount of galena. Some sphalerite was observed in copper-bearing lodes in the Silver Butte district. Secondary minerals developed within a shallow zone of oxidation include azurite, malachite, tenorite, chrysocolla, and cerussite. Gangue minerals include quartz, siderite, calcite, and ankerite, and masses of pulverulent iron oxides. Siderite was observed as a gangue mineral in quartz veins at several properties in the Star Meadow district.

Manganese as pyrolusite is present in two widely separated deposits in the map area. In northern Lincoln County, traces of copper and silver are associated with pyrolusite and galena in quartz gangue. A bog-type deposit in the Hog Heaven district is presently covered by water.

SECONDARY ENRICHMENT

The amount of secondary enrichment and depth of oxidation varies within individual districts. Gibson reported that the Tip Top (Jumbo group) gold-quartz vein contains only small amounts of unoxidized sulfides in ore mined, and at the Gloria (Little Annie) at not much greater depth than the Tip Top, very little oxidation was evident. In some areas, such as the Sylvanite district, gold-bearing veins were reported to be profitable only within the zone of oxidation. The highest grade silver ore at the Flathead mine in the Hog Heaven district was likewise enriched through oxidation. At the Blacktail property in the Star Meadow district, oxidation extends for only a few feet below the surface, whereas within the West Virginia and Foolsberg veins 6 miles south, masses of limonite are abundant for much greater vertical distances.

HOST ROCKS

Most gold-quartz veins in the Libby quadrangle are in the Prichard Formation. Only the Midas mine and a few other prospects occur in Wallace strata. Silver-lead-zinc veins in that quadrangle are in lower and middle Belt sedimentary rocks and in dikes and sills of dioritic and gabbroic composition. Copper-quartz veins are also in the sedimentary rocks of the Belt Series. In eastern Lincoln County and in Flathead County, ore deposits are confined to the Ravalli, the lower Piegan P_1 unit (believed to be equivalent to lower Wallace strata), and to fissure veins and replacement bodies in the Purcell Lava. Two of the three barite deposits described in this report are in upper Missoula Group strata about equivalent to the Libby Formation. Silver-lead veins and replacement deposits in the Hog Heaven district are confined to Ravalli sedimentary rocks and acidic rocks of Tertiary age.

ORIGIN OF DEPOSITS

Gibson (1948) reported that in the Libby quadrangle the factor localizing ore deposits is geologic structure. This is believed to be the case for most deposits within the map area. Sites of mineral deposits are related to both faulting and folding. Most major faults follow the arches of anticlines and the troughs of synclines, where built-up stresses were relieved by fracturing. This is illustrated by the position of the Rainy Creek stock and Bobtail Creek stock where nonmetallic mineral deposits and sparse metallic minerals are present in igneous intrusive bodies. Country rock may have little influence in localizing mineral deposits; metallic and nonmetallic ore bodies are found in all Belt rocks except the Striped Peak Formation. The lack of ore deposits in this formation may not be due to unfavorable host rock, however, but to both the small size of the outcrop area and the lack of favorable geologic structure within that area.

Gold-quartz veins in the Prichard Formation parallel bedding planes, and most ore is produced near high-angle crosscutting faults. The Midas gold-quartz vein and the Waylett tungsten-quartz veins approximately parallel the bedding in the Wallace Formation. Silver-lead-zinc veins fill steeply dipping fault fissures and shear zones in Belt rocks, metadiorite dikes, and to a lesser extent, metadiorite sills. The Snowstorm-Big Eight vein is in a northwest-striking metadiorite dike, and the Oro vein is in a similar metadiorite dike to the northwest, which is believed to be an extension of the Snowstorm dike. The Snowshoe veins are within the Snowshoe fault or closely parallel to it, as are veins of several other properties along this fracture.

Silver-lead replacement deposits at the Flathead mine in the Hog Heaven district are representative for the area and occur in north-striking veins and pods. Where west-trending veins and fractures intersect, ore is present in large pods. Solution holes and tubes, near the contacts of igneous with sedimentary rock, generally lie parallel to bedding planes of the Ravalli Formation or follow joints in these rocks.

Almost all copper deposits are in fissure-filled veins. The Independence property near Eureka may in part be a replacement lode. In the Star Meadow district, copper is essentially in east-trending fissure-filled veins, many of which are displaced by faults. The ore deposits may be genetically related to the acidic igneous rocks of the area although Gibson (1948) noted that in the Libby district there are no veins within these stocks or dikes, and distribution of adjacent veins seems to have no discernible relation to them. Near Warland, however, gold-quartz veins do occur in a granitic plug. Vermiculite and hydrothermal quartz-sulfide veins occur in the Rainy Creek stock. As Gibson stated (1948, p. 81), strong evidence in the Libby quadrangle, including gangue mineral associations and proximity of dikes, suggests that at undertermined depths offshoots of the exposed bodies of granodiorite and quartz monzonite may approach the ore bodies, and "even though there is no obvious direct relationship between the ore bodies and the exposed quartz monzonite stocks, the source of ores in the Libby quadrangle is the same as the source of the intrusive stocks and their accompanying dikes." The author concurs with this statement.

PLACERS

LOCATION AND ORIGIN OF DEPOSITS

In the spring of 1864 a group of Virginia City (Montana) miners journeyed to the Kootenai River country to investigate a reported gold strike. After their journey to the area, John Coleman and his associates reported that the gold strike was much exaggerated and what little gold had been discovered was already mined (Helena Mining Review, 1929, p. 4).

In 1867 a party including Stephen Allen, Anthony Cavanaugh, John Moore, and Joseph Herron traveled to Libby Creek where gold had already been discovered by Stephen Allen and Jack Sherry. At this time Libby Creek was named for Allen's daughter Libby and a nearby creek was named for another daughter Sherry; this named was later corrupted to Cherry Creek. When returning from a trip for supplies, the prospectors were attacked by Indians near the mouth of Libby Creek, the sole survivor being Joseph Herron, who escaped and walked to Wild Horse Creek diggings in British Columbia to report the massacre.

Gibson (1948, p. 25) attributed most prospecting and discovery of placers in the Libby district to prospectors from the Coeur d'Alene district who were active in the early eighties. About 1882 placer mining commenced on Libby Creek and shortly thereafter on Howard, Cherry, Ramsey, Poorman, and Bear Creeks. Callahan Creek, in the Troy district, and West Fisher Creek were prospected, the Callahan drainage producing some gold. After a flurry of prospecting in the West Fisher area, the prospectors left after determining that the gold values contained were not economic. The greater amount of placering was confined to Libby and Howard Creeks. Placer claims were located near the present site of Troy and on gravel bars and river terraces bordering the Kootenai River between Rexford and Ural. In 1939 a washing plant treated 1,100 cubic yards of gravel from the Pioneer placer at Ural; recovery was 13 ounces of gold. Kootenai River placers were not very productive, because the small size of the gold particles made recovery difficult. Source of the gold was probably lode deposits in Canada. Wolf Creek placers near the mouth of Kavalla Creek (formerly named Atlanta Creek) were discovered and located around the turn of the century. Only sporadic production from near-surface gravels was reported from the Tideman and Big Eight workings. Frank Langford located and patented several placer claims near the junction of the North Fork Flathead River and Coal Creek in Flathead County. No production has been reported from these claims.

Libby Creek flows northeast through Libby Valley, which locally attains a width of 12 miles. In the upper parts of the valley and to an altitude of 6,000 feet a sheet of glacial moraine nearly 100 feet thick covers Belt bedrock. This moraine was deposited by valley glaciers originating in the Cabinet Mountains. The glacial drift is composed of subangular particles ranging from sand to boulders 10 feet in diameter in clay matrix. Below the unconsolidated glacial moraine is an older well-indurated glacial till of subangular and rounded pebbles to boulders in yellowish-brown consolidated clay.

Earliest workings on Libby Creek were in Recent alluvium either bordering the drainage or within the stream bed; the recovered gold had been concentrated from reworked gold-bearing ground moraine through which the creek and its tributaries flowed. Schrader described the workable deposits as being confined to valleys and low places, whereas the higher slopes and benches were unprofitable. Where examined, Schrader (1910, p. 71) found that the higher deposits carried only 1 to 6 cents (gold at $20 per ounce) in gold a cubic yard, making the deposits noncommercial.

According to Schrader (1910, p. 71), the gold is irregularly or sporadically distributed from base to top of the till or in crudely horizontal beds, which possibly contain modified till. At the surface a barren oxidized zone was several feet thick. Gibson (1948, p. 73) stated, "Placer gold has not been recovered in appreciable quantity, so far as the writer knows, except from stream-washed gravels close to bedrock in the present channels of Libby, Howard, and Cherry Creeks, or from ancient channels very close to those of the present streams. Some of these gold-bearing gravels lie underneath the till and are therefore older than the till."

Lyden (1948, p. 78) described two distinct types of till found near the larger placer operations; an upper lighter colored less-indurated bed carrying the larger amount of gold and a darker bed containing less gold.

Gold from a placer on Howard Creek, described by Schrader, consisted of nuggets ranging in size from a pea to about ⅝ inch in diameter. Some nuggets had quartz adhering to or imbedded in the specimens, whereas others showed considerable rounding or wear, which Schrader attributed in part to reconcentration from preglacial placers. Most gold was deep yellow and 0.926 to 0.945 fine, and some gold was reported to be 0.970 fine. Gold values near the junction of Howard and Libby Creeks were reported as 80 to 90 cents a yard, but decreased to 20 cents a yard several miles below this area.

Origin of placer gold in Libby Creek has been attributed to quartz veins in the Prichard Formation and sulfide veins associated with the Snowshoe fault west of Snowshoe Creek (Schrader, 1910, p. 74; Billingsley, 1915, p. 13), to the near-horizontal gold-quartz veins at the headwaters of West Fisher Creek and, in part, to a dike or ledge of a rock type allied to granite porphyry, supposedly crossing Libby Creek about a mile above Howard Creek (Schrader, 1910, p. 73). Gibson described the "dike" as a mineralized layer (quartz veinlets) in the Ravalli Formation containing only very little gold or silver. One probable source of gold in Howard Creek, and in Libby Creek below the Howard Creek junction, is the northwest-striking Midas vein. The vein, if projected northwestward from the Midas mine, would trend toward Howard Lake and the low divide separating Howard Lake and the headwaters of Standard Creek. In preglacial time the ridge line between Libby Creek and Standard Creek may have been southeast of its present position, but during the periods of glaciation Standard Creek and its tributaries cut westward, capturing headwaters of tributaries that formerly flowed into Libby Creek. As Libby Creek valley was filled with moraines and drift that hinder downcutting by streams, Standard Creek was more active in downcutting. It is believed that the eroded part of the Midas vein supplied gold to the Libby Creek and Howard Creek placers. Undoubtedly, quartz-sulfide veins along the Snowshoe fault were sources of placer gold along Big Cherry Creek.

Placer deposits on Wolf Creek and Vermilion River are found not on bedrock but in upper gravels within several feet of the surface. They are believed to be derived from gold-bearing quartz veins in the nearby area.

DESCRIPTION OF PLACERS

LIBBY DISTRICT

BOLYARD PLACER

About 1 mile up Howard Creek is a placer owned by L. W. Bolyard of Libby (Fig. 11). This placer, which was active in 1964, was originally the Vaughan and Greenwell mine, productive between 1889 and 1909, and was part of the ground owned by Libby Creek Gold Mining Company.

At the property Mr. Bolyard has constructed a small dam and ditch to carry water for hydraulic mining to a ½-acre area where gold-bearing cemented till was exposed by bulldozing. The till, containing subangular pebbles and cobbles, can be separated from the clay binder by hydraulicking; the finer gold-bearing till is washed in sluice boxes to recover the gold.

NUGGET PLACER

Gibson (1948, p. 124) described the Nugget placer as consisting of several claims on Libby Creek, about a mile below the mouth of Bear Creek. A small production was reported in Mineral Resources (1916). Production was also reported for 1939 (Minerals Yearbook, 1940). At the time of Gibson's visit (1932) gravels were being sluiced from the present channel and a former channel where the pay streak was concentrated on bedrock. Water was obtained from Libby Creek, and the gravel was mined by dragline and scraper bucket. The property was inactive in the early 1960's.

RED GULCH PLACER

During 1931, the Red Gulch placer was mined by hydraulicking the gravels in an old channel on Libby Creek near the mouth of Cherry Creek. A pay streak in partly cemented stream gravel above bedrock is overlain by laminated silt. Above the silt is a mixed soil containing striated pebbles and boulders. The gravel is reported to yield 60 cents to about $1 a yard. A short distance below this placer is the Bear Creek placer, formerly the Millander placer, active in 1915.

LIBBY CREEK GOLD MINING COMPANY

The Libby Creek Gold Mining Company in 1932 owned placer ground on Howard Creek and on Libby Creek above its junction with Howard Creek. During Gibson's visit (1932), activity was almost confined to Libby Creek, above the Howard Creek confluence, and upstream from ground owned by the Libby Placer Company (formerly the Goldhill-Montana-Kootenai group). At this location, hydraulic mining was carried on above old pits where the ground is supposed to average about 22½ cents a cubic yard. Gold is concentrated near the surface of the till, but the underlying till carries little value. Gibson (1948, p. 126) described the section as glacial till overlain by tough cemented hardpan containing subangular pebbles, in turn overlain by unconsolidated glacial till; the thickness of this section locally is more than 50 feet.

The Minerals Yearbook (1940) reported that between June 1 and October 20, 1939, the Davis & White Mining Company treated about 33,000 cubic yards of gravel from the "Liberty" placer on Libby Creek. A 1-cubic-yard power shovel and dryland washing plant were used to recover the gold. Lyden (1948, p. 76) reported that during the summer of 1947 the "Liberty Placer Mines"

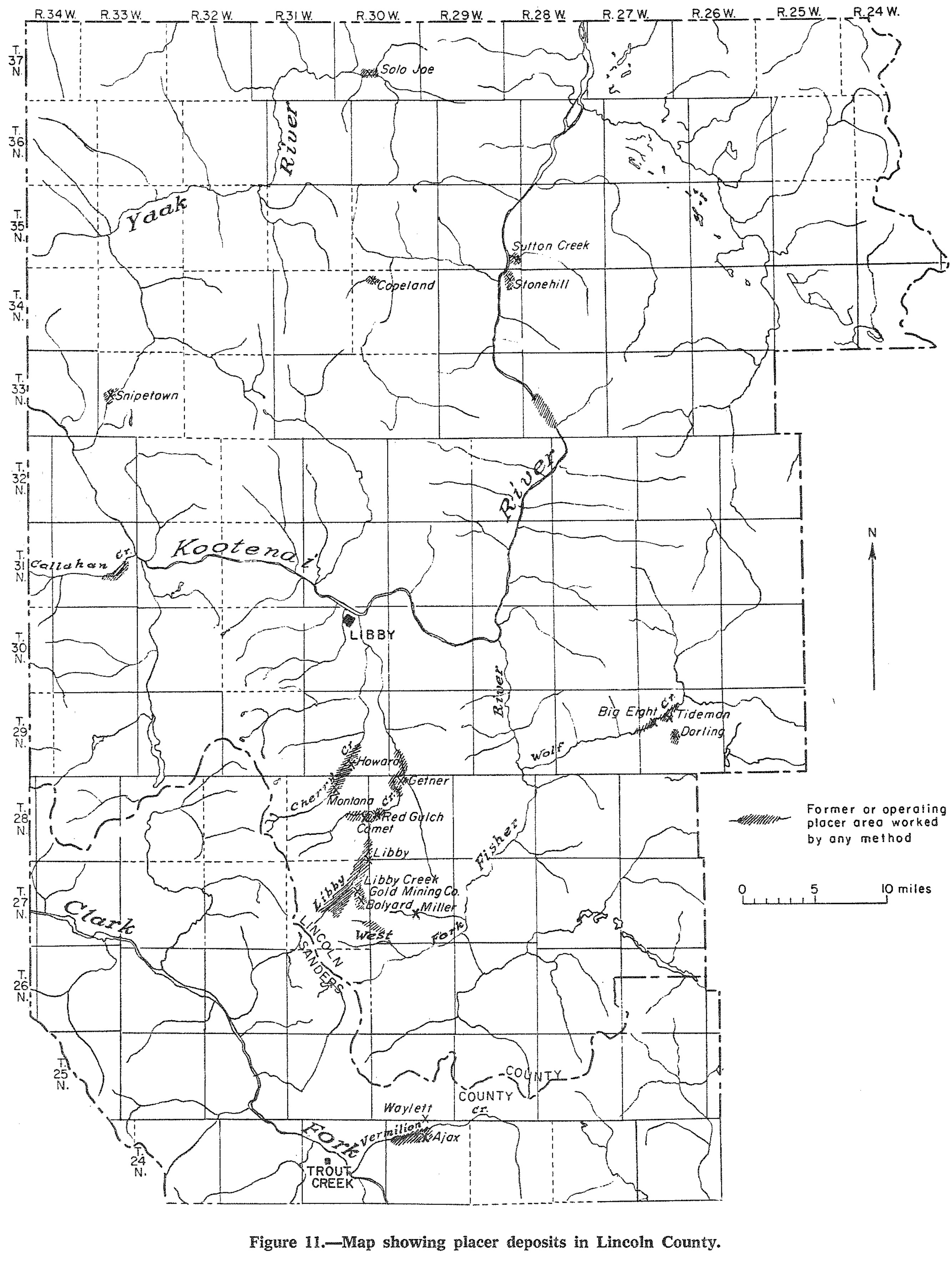


Figure 11.—Map showing placer deposits in Lincoln County.

washed more than 15,000 cubic yards of bench gravels estimated to average 42 cents a cubic yard. A gross value of $6,600 was realized from this operation. Two hydraulic giants and bulldozers were used to treat the gravels.

COMET PLACER

The Comet placer consists of several claims on Little Cherry Creek near its junction with Libby Creek. The ground was purchased by the Comet Mining Company in 1908 and hydraulicked until 1916, some gold being produced in 1910 and 1911. The property was active in 1921, but seemingly has been inactive since that date. The claims are now owned by the J. Neils Division of the St. Regis Paper Company. It is reported that the stream-gravel pay streak is overlain by a lean till so thick that removal is too costly to allow a profit.

LIBBY PLACER

Libby placer, formerly the Brophy placer, is on the east side of Libby Creek near the confluence of Ramsey Creek. Development amounts to a 1,600 by 400-foot pit, chiefly in till. In 1931 several miners were placering ground a quarter of a mile below Ramsey Creek in gravel very close to bedrock. Here Gibson (1948, p. 127) observed that although the surface material on the stream banks carried some gold, only the gravel close to bedrock was rich enough to work. The placer was active in 1915, 1931-32, and 1939. It was inactive in 1958.

MONTANA PLACER

The Montana placer, opened in 1905, was located on Cherry Creek near its confluence with Snowshoe Creek. In 1915 under new ownership the property yielded a small profit after a considerable sum was spent in development. Subsequently the operation was regarded as unprofitable. Some activity along Cherry Creek was recorded in 1924, 1930-31, and 1939. On these claims as elsewhere along Cherry Creek gold is confined to narrow deposits along or near present stream channels. Lyden (1948, p. 79) reported that total production did not exceed a few thousand dollars. Placer gold undoubtedly originated from veins in Ravalli quartzite between Cherry and Snowshoe Creeks. The ground was inactive during the period 1958 to 1964.

HOWARD PLACER

The late Harry Howard of Libby worked a placer along Cherry Creek near the mouth of Smearl Creek and recovered gold from the crevices in the creek bed. The placer was active until about 1955. It is reported that some gravel ran 50 cents to $1 a yard. These claims were inactive in 1959.

YAAK RIVER DISTRICT

SNIPETOWN PLACER

The Snipetown placer is on a bend of the Yaak River 3½ miles below Yaak Falls. It was operated during 1934 and 1935. The placer ground was leased from E. Johnson who homesteaded in the area. The operators were R. Moore, J. Lewis, M. D. Powely, and Mr. Packingham of the U. S. Immigration and Custom Services.

The gold-bearing gravel was found on benches above the present river level. The gold value ranged from 90 cents to $3 a cubic yard in a pay streak found in clay above bedrock. Some flake gold and some nuggets about matchhead size were recovered in the sluicing operation.

A flume was constructed to bring water from upriver. Sections of this flume, sluice boxes, and collapsed buildings still remain at the site. Development consists of a few test pits on the gravel bench, and a caved adit driven in Ravalli siliceous argillite at the river bend. Higher terraces may contain gold-bearing gravel, but mining was confined to a lower terrace.

The gold was probably derived from the Goldflint-Keystone vein in the Sylvanite district, about 7 miles above the placer.

CHINA LAKE PLACER

It has been reported that placers yielded some gold from China Creek and around China Lake during early placer mining operations in the Libby area. No evidence of placer mining now remains, and placer production from the China Lake area could not be verified.

SOLO JOE PLACER

The Solo Joe placer is on the East Fork of the Yaak River, on a slightly elevated bench bordering the river. Tailings cover approximately half an acre. The original locator was Solo Joe Perriault, a prospector and homesteader in the Yaak area, who did the original development in the early 1900's. A Captain Mappot worked the placer from about 1938 to 1940. Production from the property has been small.

COPELAND PLACER

The Copeland placer and prospect are about 1½ miles west of the mouth of Copeland Creek. The placer is in Recent creek gravel; a few colors were panned from surface gravel and sand bordering the stream. A collapsed cabin, an old flume about 75 feet long, and a water wheel remain at the placer site. Production from the property was not determined, but it seems to be very small.

An inaccessible adit is situated about 200 to 250 feet north of the placer on the north bank of Copeland Creek. A narrow trail ascends a prominent talus slope to the caved tunnel. The country rock is Prichard argillite, which strikes N. 15° W. and dips 50° SW. Vertical joints striking N. 70° W. are prominent above the adit on the hillside. The dump is covered with diorite porphyry containing very sparse chalcopyrite and calcite. The dump rock consists of biotite-quartz-carbonate matrix containing large sericitized feldspar phenocrysts. It seems probable that a dike or small stock is cut by the tunnel a short distance from the portal. The size of the dump indicates that the tunnel is probably about 40 to 60 feet long.

THOMPSON LAKES DISTRICT

MILLER PLACER

During the 1930's O. V. Miller and P. Church of Libby staked 1,200 acres of potential placer ground 2 miles south of Teeters Peak along West Fisher Creek. All except one 20-acre claim were subsequently dropped. Development work on this claim consists of a 100-foot shaft, now inaccessible, and a nearby churn drill hole to a depth of 110 feet. The shaft encountered one 10-foot zone of silt at a depth of 15 to 25 feet. No production has been reported from the property.

Mr. Miller reported that gravel, sand, and silt in the shaft average 12 to 16 cents per cubic yard in gold. He stated that the gravel in sec. 3 (Northern Pacific Railway section?) may be richer.

Color can be panned from most creek gravel in the upper reaches of West Fisher Creek and its tributaries. Some test holes were drilled in the flats near West Fisher Creek. One hole reached bedrock at a depth of 107 feet, and three other holes were stopped in gravel at depths of 50 feet. The results of this drilling are unknown.

TIDEMAN PLACER

The Tideman placer was located by Knute Tideman about 1900. The most extensive workings are near the junction of Kavalla (Atlanta) and Wolf Creeks. This part of the claim is developed by fairly extensive pits averaging 3½ feet deep over about half an acre. The pits are at a slightly higher altitude than Wolf Creek. The ground is presently owned by J. Neils Division of the St. Regis Lumber Company.

Gold occurred as medium to coarse nuggets from surface to a depth of 2 feet. Albert Johnson reported recovering an ounce of gold a month during the early thirties. Some of the better gravel ran $1 to $1.50 a wheelbarrow load. No accurate record of production is available, but some gold was recovered in 1929, 1930, 1932, 1934, and 1935. In 1934, production was 19 ounces of gold (Mineral Resources).

BIG EIGHT PLACER

The Big Eight placer claim was located in June 1902 by J. R. Listle, W. F. Mulaney, F. C. Sauerbier, Knute Tideman, S. J. Jaqueth, J. J. Hubbard, F. L. Gray, and W. H. Griffin. The patented claim was later acquired from the Listle estate by the J. Neils Lumber Company. The property consists of 160 acres on Wolf Creek between Tamarack and Kavalla Creeks (Fig. 12).

The ground along Wolf Creek was worked, but no record of production or development is available.

DARLING PLACER

One 20-acre placer claim was located in 1929 by Art Darling about ½ mile up Kavalla Creek. Development work consists of several pits and trenches. Remnants of old sluice boxes remain to mark the site of operations. Mr. Darling reported that coarse gold was associated with black sand, small garnets, and pyrite cubes from the surface to bedrock. Placer gold was spotty and ran only a few cents to $1 a cubic yard. A small amount of gravel yielded $1 per pan in gold. Production from the claim amounted to about 20 ounces over a period of 2 years.

GETNER PLACER

The Getner placer was located by J. S. Getner and associates on Libby Creek. The property was active in 1929 when Gibson (1948, p. 128) was mapping the Libby quadrangle. Stream gravels near creek level a short distance below Crazyman Creek were sluiced for gold. The property has been inactive for the last 30 years, and no record of production is available.

OTHER PLACERS

Two abandoned placers were noted in sec. 9, T. 28 N., R. 30 W., 4 miles southeast of Big Hoodoo Mountain, a short distance above the Getner placer. Considerable sluicing of gravel is indicated by tailings dumps in the area.

In the 1930's Bud Jones, Sr., of Kalispell, placered in Tensaw Creek and located a claim on Forest Service ground about midway up the drainage. There is no report of production from the placer.

Color can be panned from the gravels near the mouth of Cow Creek, a tributary of the West Fisher River (Art Darling, personal communication).

URAL AREA

STONEHILL PLACER

The Stonehill placer is situated on a gravel bench 10 to 12 feet above and on the east side of the Kootenai River half a mile south of Stonehill, a Great Northern Railway siding. The property, which is on private ground, was operated for a 2-week period during the early 1930's. It is reported that about $80 in fine gold was recovered at that time. The fine gold occurs about 2 feet below the surface in fine to coarse sand and gravel. Frank Logsdon of Rexford is reported to have worked the property at one time. Sluicing was confined to an area 40 by 90 feet. Remnants of old sluicing equipment and iron pipe remain at the site. A string of colors can be recovered from each pan of material.

SUTTON CREEK PLACER

The Sutton placer is at the mouth of Sutton Creek, 9½ miles from Rexford. The late Marian Fishel of Kalispell operated the property. A washing plant designed by him recovered a considerable amount of gold-sand concentrate assaying about 41.5 ounces of gold to the ton.

PIONEER PLACER

The Pioneer placer is on the Kootenai River near Ural. Minerals Yearbook (1940) reported that L. C. Curtis & Sons operated a dragline and stationary washing plant in December 1939, treating about 1,100 cubic yards of gravel, from which 13 ounces of gold was recovered (Lyden, p. 80).

The gravel bar at this property carries 41 cents a cubic yard recoverable gold, and possibly other gravel bars in the area can be profitably worked by mechanical methods. The placer gold is believed to have been transported from Canadian lode deposits near the headwaters of the Kootenai River.

NORTHERN THOMPSON FALLS AREA

AJAX PLACER

The Ajax gold placer is on the Vermilion River below the mouth of Lyons Gulch in the Thompson Falls area, Sanders County. The two unpatented claims, Ajax No. 1 and 2, were relocated by the late Albert Thayer in 1948. The ground has recently been leased to Frank Duval of Spokane.

Mr. Thayer reported that the ground was originally located and worked by Ed Coleman and Mr. Rowdy of Butte, who produced a total of $90,000 from these and other Vermilion River claims between 1900 and 1906. Between 1930 and

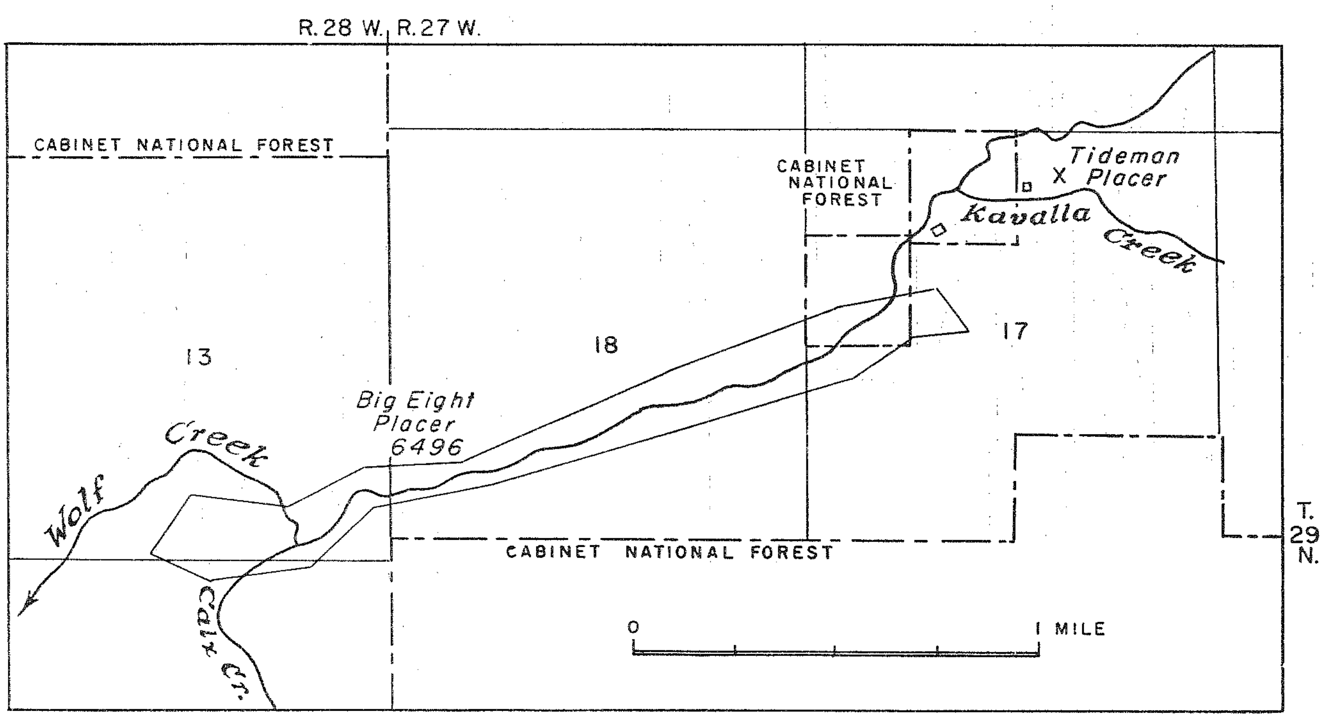


Figure 12.—Sketch map of Big Eight placer, Lincoln County.

1936, Thayer reported the claims produced $60,000 to $70,000. Production since 1948 has amounted to about $3,500.

The largest tailings pile covers an area about 100 by 400 feet. Mr. Thayer worked (1961) a small strip of ground adjacent to the river; he used a 6-foot sluice box and reported that only the upper 6 feet of gravel was productive, the ground averaging about $1 a yard in coarse gold.

According to local residents all placer production of consequence from the Vermilion River placers came from ground below the junction of Lyons Creek with the Vermilion River. This suggests that the source of the placer gold was the Lyons Creek area. The possible exception is an unverified report of a placer operation in Sims Gulch described under "Other Placers."

WAYLETT PLACER

Harry K. Waylett of Star Route, Libby, is presently developing a placer in lower Lyons Creek where he owns the mineral rights to 160 acres. The ground was homesteaded by Fred

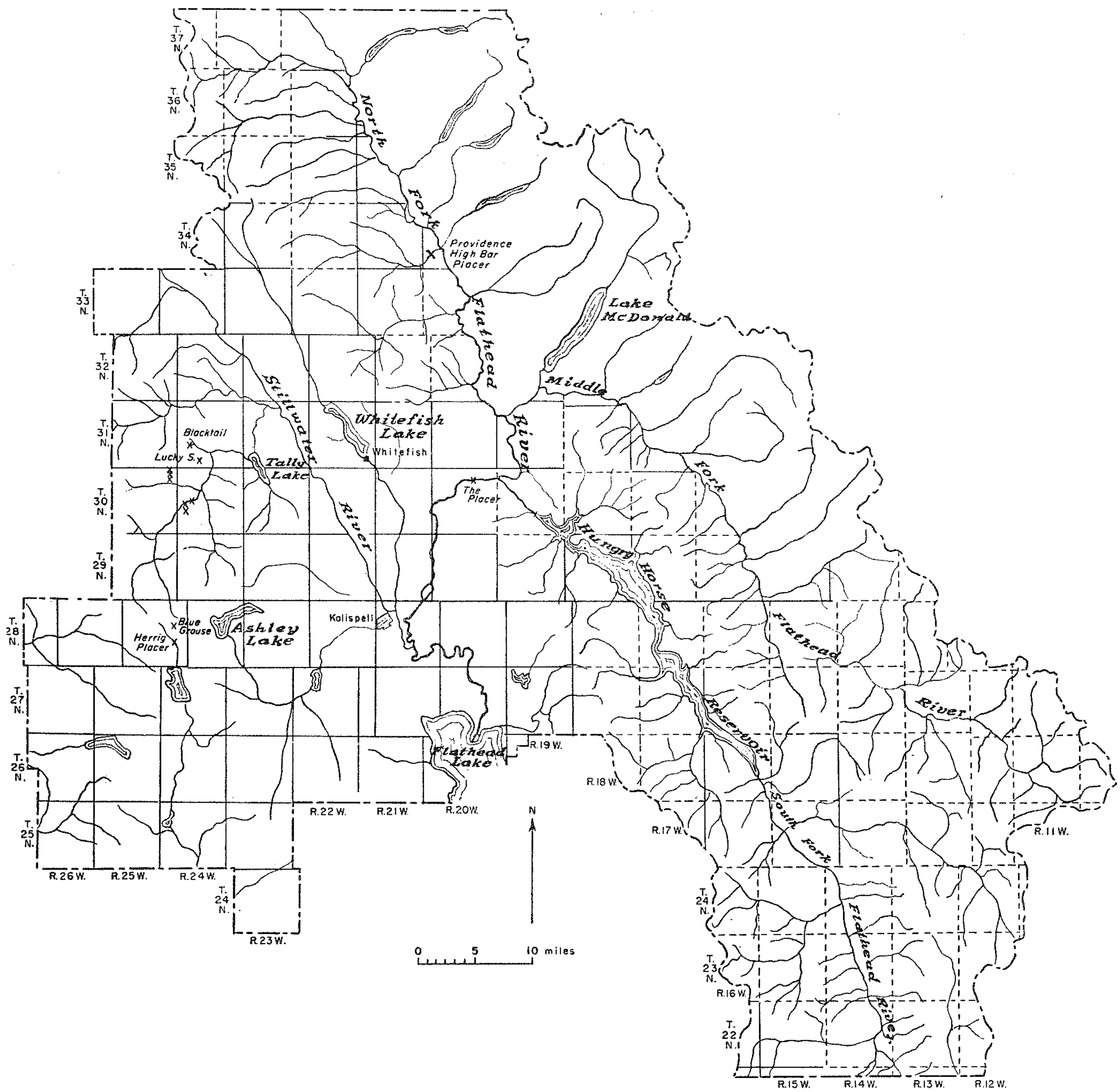


Figure 13.—Map showing placer and some lode deposits in Flathead County.

Hayles of Kalispell and was acquired by Harry Waylett's father in 1919.

OTHER PLACERS

Albert Thayer of Vermilion River stated that about 1890 his father attended an inquest into the deaths of two placer miners, killed in a cavein of a vertical 86-foot shaft in Sims Gulch approximately 2½ miles above its junction with Vermilion River. According to Mr. Thayer, the coroner's party removed 2 or 3 pounds of gold from the sluice box and disposed of a quart bottle filled with placer gold. The writer and others have not been able to determine the location of the shaft, which may have been filled with gravel and mud during the annual spring runoff.

PLEASANT VALLEY AREA

HERRIG PLACER

A sluice box composed of several sections was once installed on Herrig Creek a short distance south of its junction with the North Fork of Herrig Creek, in Flathead County (Fig. 13). Local residents stated that some placer mining was done in this area prior to 1900, possibly in the eighties.

Glen Bauska and the Poston brothers examined the sluice boxes in 1929 and 1940, respectively, and the Postons panned colors and recovered small globules of mercury from tailings piles. Parts of an old diversion dam remained as late as 1940. The gold-bearing gravels may have been packed in; no workings were found in the area. Test pits and evidence of placer mining can be found in adjacent areas.

LANGFORD PLACERS

Frank Langford located and patented the Placer (M.S. 3335), Providence placer (M.S. 3374), and High Bar (M.S. 3375) at the junction of the North Fork Flathead River and Coal Creek (Fig. 14). The claims were surveyed for patent in January 1891. The Providence placer, 150.42 acres, was developed by a 60-foot open cut and discovery shaft; the High Bar claim, 131.35 acres, by a 38-foot tunnel and discovery shaft; and the Placer by a 200-foot tunnel and discovery shaft. Production from the property is unknown.

The claims are now part of the coal lands along Coal Creek, which are owned by the First National Bank of Butte.

The Placer patented claim (M.S. 3334), east of Badrock Canyon, was surveyed for patent in January 1891. The property, 155.25 acres, at time of patent application was developed by a discovery shaft, ditch, and two dams. The John M. Lynch claim bordered the "Placer" to the north. The ground is thought to be owned now by W. and E. Skyles and The Anaconda Company.

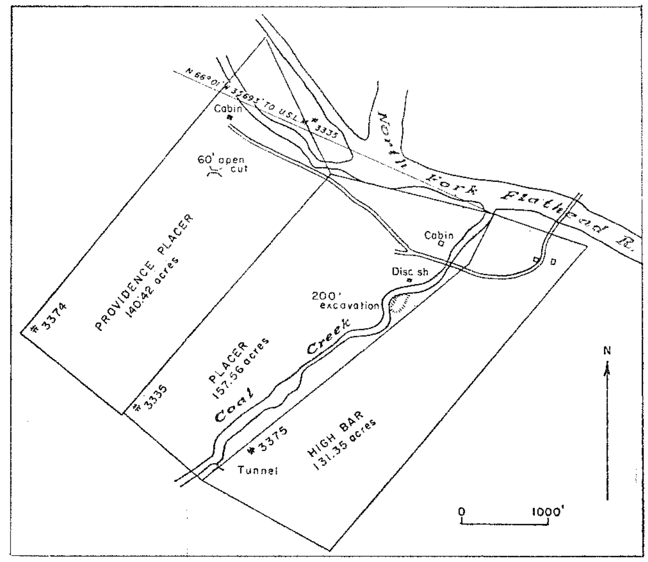


Figure 14.—Frank Langford placer claims, T. 34 N., R. 20 W., Flathead County.

OTHER PLACERS

Small piles of gravel believed by Glen Bauska to be placer tailings were observed 1½ miles northwest of Ashley Lake. No extensive work was done in this area, and the ground, if tested, must have been unproductive.

DESCRIPTION OF LODE MINING PROPERTIES

LIBBY DISTRICT

SNOWSHOE

The Snowshoe mine was discovered in October 1889 by A. F. Dunlap and J. Abbot, who located claims on both sides of Snowshoe Creek (Fig. 15), about 14 miles south-southwest of Libby. Other partners in the venture were B. Parmenter and H. G. Lougee. The four patented claims forming the Snowshoe group are the Rustler (MS 5315), Snowshoe Quartz (MS 5316), Porcupine (MS 5317), and Chinook (MS 5278). The Howard property (Silvertip) adjoins the Snowshoe group on the south. Wood (1892), a very early visitor to the property, briefly described the vein on Snowshoe Creek.

Earliest lessees of the property were the Chicago and Montana Mining Company, who erected a mill in the early nineties. Extensive development commenced later, when the mine was acquired by an English syndicate, the Pacific Northwest Mining Company, who at one time

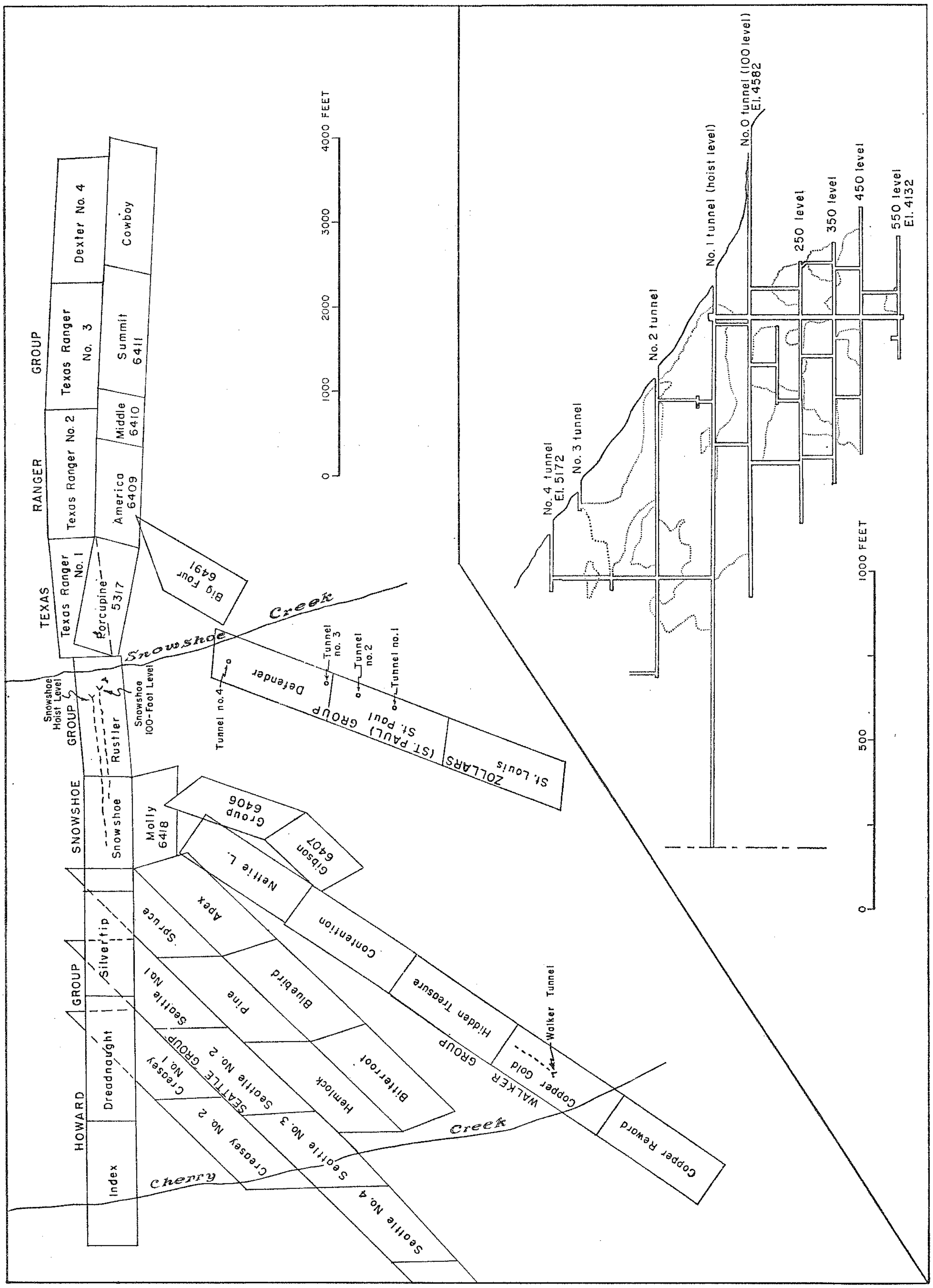


Figure 15.—Claim map of the Snowshoe mine area and north-south section through Snowshoe mine, Libby district, Lincoln County.

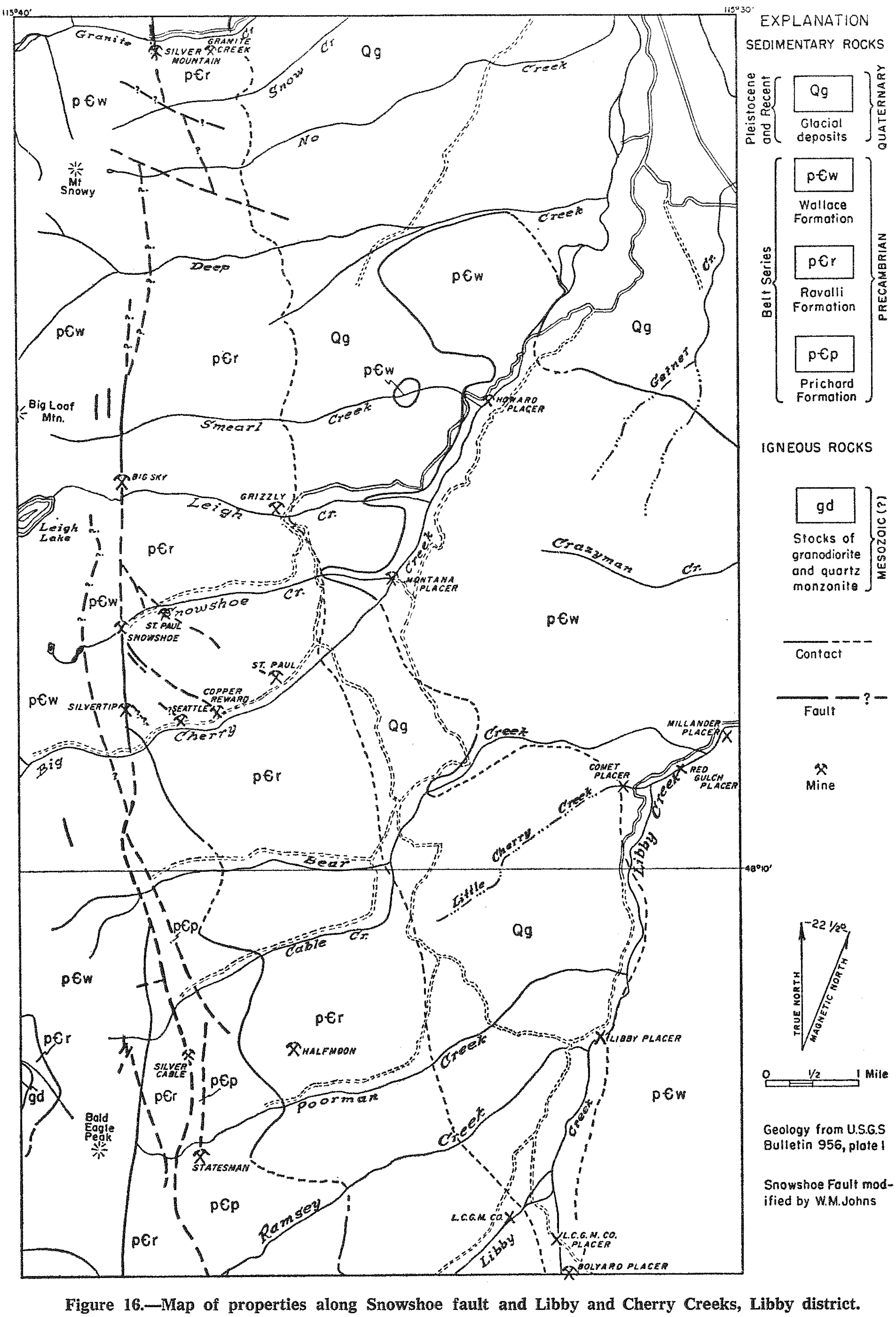


Figure 16.—Map of properties along Snowshoe fault and Libby and Cherry Creeks, Libby district.

employed 250 men and operated the property on a three-shift basis.

Hunter and Byrne (1898) reported that in July 1898 the Snowshoe was leased for a period of time to D. D. Bowers, who employed 32 men and shipped ore to Great Falls. Development at this time amounted to Tunnels 1 and 2, driven on the vein for 750 feet and 230 feet respectively, and a connecting raise. In 1900 the Snowshoe produced for 6 months, but it was idle during 1901 and until early in 1902, when it was purchased by D. D. Bowers.

The Inspector of Mines Report (Walsh and Orem, 1906) stated that the Snowshoe operated all of 1905 and part of 1906 and that 500 feet of development was completed in 1906. The property employed 90 men, and a 225-ton concentrating plant treated the ore. Development amounted to five tunnels 470 to 1,700 feet long and a 550-foot shaft sunk from the lowest level; vertical height between vein apex and lowest workings amounted to 1,700 feet. The mine was idle in 1910 because of stockholder litigation. In 1911 the Snowshoe mine was purchased by W. Jennison and operated thereafter for only a short time. Ore shipments from the Snowshoe were reported in 1909, and 1911 to 1912. The mine was active throughout 1912, and 50 to 75 men were employed (Walsh and Orem, 1912). Increased gold values were reported at lower levels. A. E. Riter, receiver, operated the property for a short period in 1912. In 1940, C. H. Foot, G. H. Grubb, and H. Keith purchased the group of claims and in that year leased the ground to B. Sharp and T. Grow, who installed a portable selective flotation concentrator and subsequently milled developed ore, mine dumps, and tailings. Between 1940 and 1942 the lessees treated several thousand tons of ore, and between 1940 and 1945 they produced concentrates reportedly valued at $125,000. In 1945 the property was under lease to the Standard Silver Lead Company, Spokane, Washington.

Prior to 1958 the St. Paul Lead Company, Inc., and the Merger Mines Corporation leased the Snowshoe claims and the St. Paul and Seattle groups (Fig. 16). A 100-ton flotation mill was erected to treat ores from these properties. Subsequently, the Sydney Mining Company acquired the St. Paul Lead Company and Merger interests, but the property has been inactive since 1964. Total production from the property amounts to about 145,000 tons of ore valued at $1,211,000.

Development work at the Snowshoe totals 11,000 feet of workings, including adits, connecting raises, two shafts 550 and 475 feet deep, and intermediate levels from the shafts. Four adits and connecting raises, totaling 6,550 lineal feet including the hoist level, are above the water table. Four intermediate levels, serviced by a vertical shaft extending from the zero tunnel (lower tunnel in Fig. 15) to the 550 intermediate, are now under water. Billingsly (1915) described the ore shoot as 2,000 feet long and 5 feet wide. The ore body is developed for an overall depth of 1,040 feet from the highest adit down to the 550 intermediate.

The ore is in a fissured and sheeted zone (Snowshoe fault) that attains a maximum width

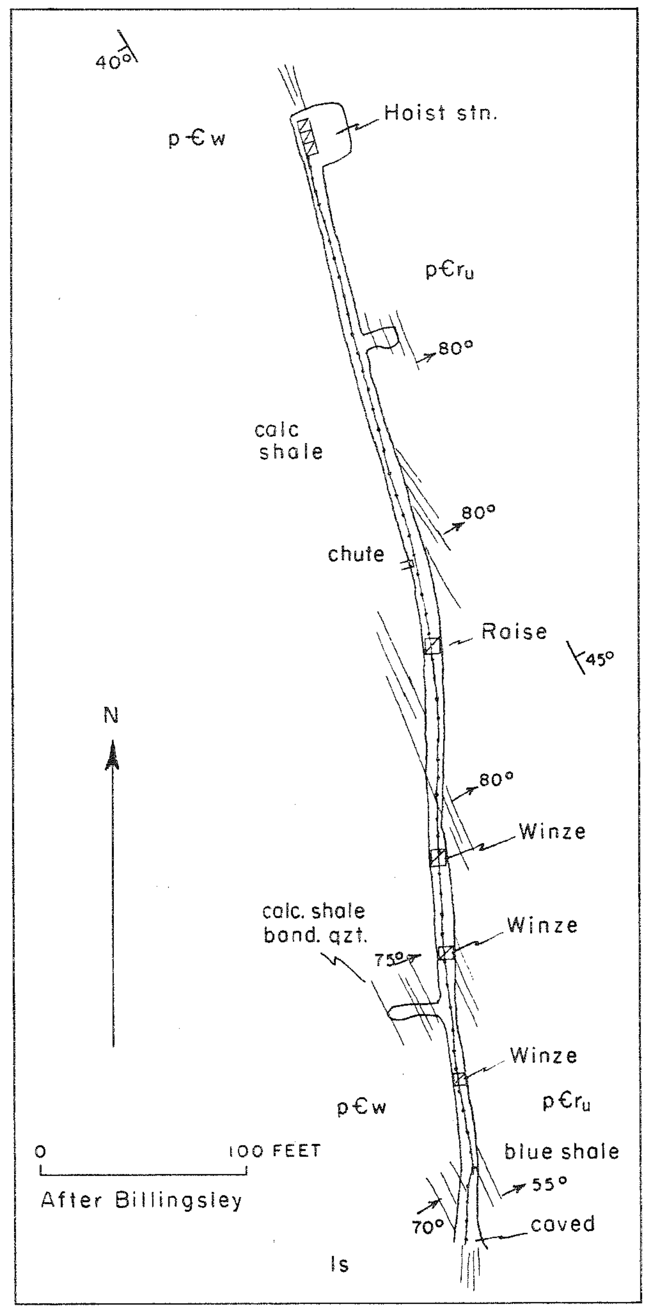


Figure 17.—Adit 1 (hoist level) Snowshoe mine, Libby district. (After Billingsley, 1915.)

of 12 feet, most of the zone being about 5 to 6 feet wide. A parallel vein is reported 75 feet east of the Snowshoe vein. The fissure vein strikes N. 5° to 12° W. and is nearly vertical (Fig. 17, 18). Wall rock east of the structure is dark-blue-gray sericitic quartzitic argillite and quartzite of the Ravalli Group, whereas that on the west is gray calcareous shale and white limestone of the Wallace Formation. The sheared and sheeted zone is at or near the axial plane of the anticline.

Veins a fraction of an inch to about a foot wide are enclosed in the shear zone. Irregular masses of silver-bearing galena and sphalerite, some pyrite, and less abundant chalcopyrite and arsenopyrite are enclosed in a gangue of quartz, siderite, carbonate rock, and clay. Grade of ore from stopes is reported to have averaged 10 percent lead and 3 ounces silver (Sandvig, 1947). Some gold was recovered from the ore during milling, and MacDonald (1906) reported gold content of about $1.50 a ton in the upper part of the vein.

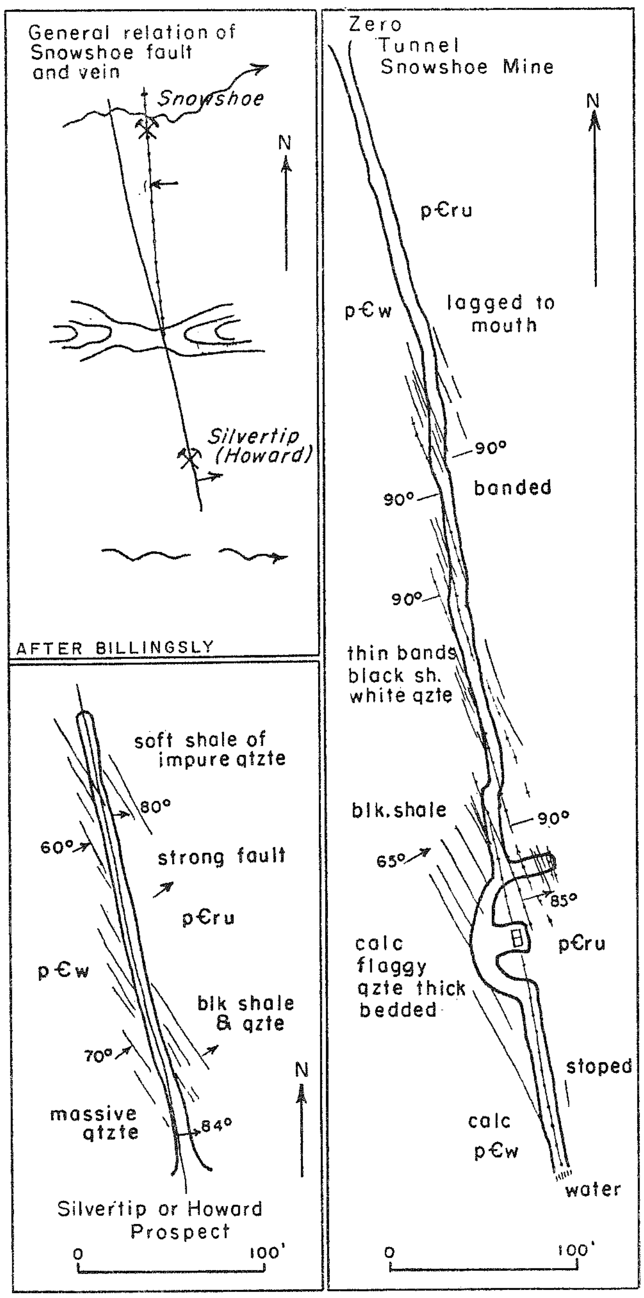


Figure 18.—Zero tunnel, Snowshoe mine, and Silvertip prospect, Libby district. (After Billingsley, 1915.)

Gibson (1948) noted that the vein quartz was shattered and brecciated and that the sulfides showed preference for the shattered quartz, indicating that fault movement followed premineral quartz veins. Slickensides on sulfide and gangue minerals in the shear zone indicate additional movement after emplacement of the ore and gangue minerals.

On the north slope of Snowshoe Creek, adjoining the Porcupine claim on the north, are four patented claims on the Snowshoe fault; the America (MS 6409), Middle (MS 6410), Summit (MS 6411), and Big Four (MS 6491). Charles O'Rourke of Butte is reported to own one-third interest and Lincoln County the other two-thirds interest in these four claims.

SILVERTIP

The Silvertip prospect (Fig. 16), formerly the O. A. Howard prospect, is on the north side of Cherry Creek, within a sparsely mineralized part of the Snowshoe fault south of the Snowshoe mine. The prospect is developed by several short adits and pits. The three unpatented claims that constitute the group are the Index, Dreadnaught, and Silvertip. The principal adit follows for 250 feet a strong fault that strikes N. 10° W. and dips 80° E. (Fig. 18). Additional work has advanced the face 300 feet from the portal. Higher up the slope the Snowshoe fault strikes north and is vertical. Brown and dark-gray arenaceous argillite of the Prichard Formation is east of the fault, whereas calcareous and quartzitic argillite of the Wallace Formation is west of the fault. At the portal of the adit, drag folds suggest downthrow to the east as the latest movement. Shearing, which trends about N. 30° W. and dips 60° to 70° NE, continues into the wall rock on both sides of the structure. Fault breccia, gouge, and vein quartz occupy the 3-foot fault zone in some of the workings. Metallic minerals include galena and its alteration products cerussite and anglesite, and pyrite that has altered in part to iron oxides. The property was active in 1926.

ST. PAUL

Three unpatented claims, the Fern, Faith, and Topsy, were originally the Defender, St. Paul, and St. Louis. They are owned by Walter C. Zollars of Libby, who acquired the property from Mrs. S. N. Plummer, Mike Shanahan, and Sam Ratekin. The claims trend northwest from the north side of Cherry Creek to the south side of Snowshoe Creek (Fig. 16). The Cherry Creek road crosses the southeast end of the property, where there is a cabin and an inaccessible adit. The workings on the south side of Snowshoe Creek are reached by a road from creek level. The group was leased to the Oro Mining Syndicate of Kellogg, Idaho, and Silver Star Mine, Inc.; development work commenced in 1955. Production in excess of 350 tons has been reported from the Snowshoe Creek workings.

Additional development includes a 600-foot adit, now caved, on the Cherry Creek side, and three southeast-trending adits south of Snowshoe Creek and about half a mile east of the Snowshoe mine. These three adits total 670 feet in length, but only the lowest adit (No. 3) was accessible in 1964. All workings are in Ravalli quartzite and argillite, which strikes N. 5° to 20° W. and dips 35° to 45° NE.

The Cherry Creek adit (Gibson, 1948) is on a fault zone that strikes about N. 65° W. and dips 65° SW. The zone contains 3 feet of brecciated rock and a few inches of gouge, stained with limonite but containing only sparse sulfides. The adits above Snowshoe Creek, probably on the same fault, follow the fractured zone, which here is 14 to 42 inches wide, and averages about 26 inches wide. At the lower adit the fault strikes N. 50° to 62° W. and dips 65° SW, and the fault width is about 18 inches.

In the Wallace Miner, dated September 22, 1955, A. L. Osborn of the Oro Mining Syndicate reported that development work on the No. 3 adit had extended 110 feet in ore averaging 18 inches wide and carrying combined values of 40 to 50 percent lead and zinc, and silver values averaging approximately 3 ounces a ton, and that about 300 tons of good ore has been stockpiled from development work. The tenor and thickness of the described ore body have not been verified. At the face of adit No. 2, 100 vertical feet above No. 3, an 18-inch vein was reported to assay 16.6 percent lead, 15.8 percent zinc, and 4 ounces silver a ton, likewise unverified. Sulfide minerals include galena, sphalerite, and sparse chalcopyrite in quartz gangue. Within the upper oxidized parts of the vein, copper carbonates, cerussite, and manganese oxides are present. Sulfide minerals occur both disseminated and in veinlets associated with sericite and minor calcite.

COPPER REWARD

A group consisting of five claims, Copper Reward, Copper Gold, Hidden Treasure, Contention, and Nellie L., was formerly known as the Walker group. Four of the claims are on the north side of Cherry Creek. The fifth claim (Copper Reward) is south of Cherry Creek. The property is developed by a 440-foot adit (Walker tunnel, now inaccessible) and several pits and short adits. Workings are in the Ravalli quartzite, which here strikes about N. 25° W. and dips 35° NE.

On the north side of Cherry Creek a vertical mineralized shear zone, striking N. 30° to 35° W., contains 3- to 6-inch veins of sulfides associated with quartz and carbonate rock. Pyrite, arsenopyrite, and galena are the most abundant sulfides; chalcopyrite and sphalerite are less abundant. Replacement by sulfides extends a short distance into the wall rock. Oxidation products include anglesite, malachite, azurite, and limonite. The property has been inactive for several years.

The Molly Gibson group comprises three patented claims, the Molly Gibson (MS 6406), Osso Negro (MS 6407), and Moccasin (MS 6418), which adjoin the Nellie L. claim on the north and east. This group is reported to be owned by Charles Newlin, Marion, Montana. Development is reported to consist of one adit, now caved as the mine is inactive.

SEATTLE

Five unpatented claims, Seattle No. 1 to 5, are located on the north and south sides of Cherry Creek. This group was reported leased to the St. Paul Lead Company prior to 1958, but it was inactive in 1964.

On the north side of Cherry Creek, Seattle No. 1, 2, and 3 are located on a quartz vein that strikes N. 45° to 50° W. and dips 35° to 40° NE. This vein approximately parallels bedding in gray argillite and white quartzite of the Ravalli Group. The quartz vein ranges in width from several inches to 4½ feet and contains, in order of abundance, pyrite, galena, sphalerite, and chalcopyrite. Limonite from the iron disulfide occurs in the oxidized parts of the vein. In places the vein and veinlets cut bedding planes, and there they have steeper dips than the country rock.

GLACIER SILVER-LEAD

The Glacier Silver-Lead property was described by Billingsley (1915) as the Hazel T. and by Gibson (1948) as the Lukens-Hazel mine. It is

6 miles southwest of Libby on the north side of Shaughnessy Creek. The property consists of seventeen patented claims, which have been acquired by the J. Neils Division of the St. Regis Paper Company. The mill was inactive in 1936 but some mine development was being carried on then. The property was inactive in 1964, and several buildings still standing are in a dilapidated condition. The 325-ton mill has been dismantled. By 1930, development work totaled more than 10,500 feet, and only some of the underground workings were inaccessible. At this time the mine was developed through No. 4 level, a drift striking northwest through the Wallace Formation. Probably this is the property described by Walsh and Orem (1912) as the Shaughnessy Hill group, consisting of tunnels 700 and 500 feet long, which in 1910 were operated by A. J. McCorkle and J. Town, who shipped several carloads of gold-lead ore in 1910 (Fig. 19).

In 1915 an ore shoot 3 to 4 feet wide and 200 feet long (west vein?) was being mined through tunnels on the west slope of Shaughnessy Hill to a depth of 300 feet. The ore minerals consisted of pyrite, galena, and sphalerite in a quartz gangue, the ore minerals replacing calcareous argillite along bedding planes. In 1915 only a small amount of ore remained above the lowest tunnel level (the ore body having been stoped above the next level), and development of any additional ore reserves from this ore shoot would have necessitated sinking a shaft.

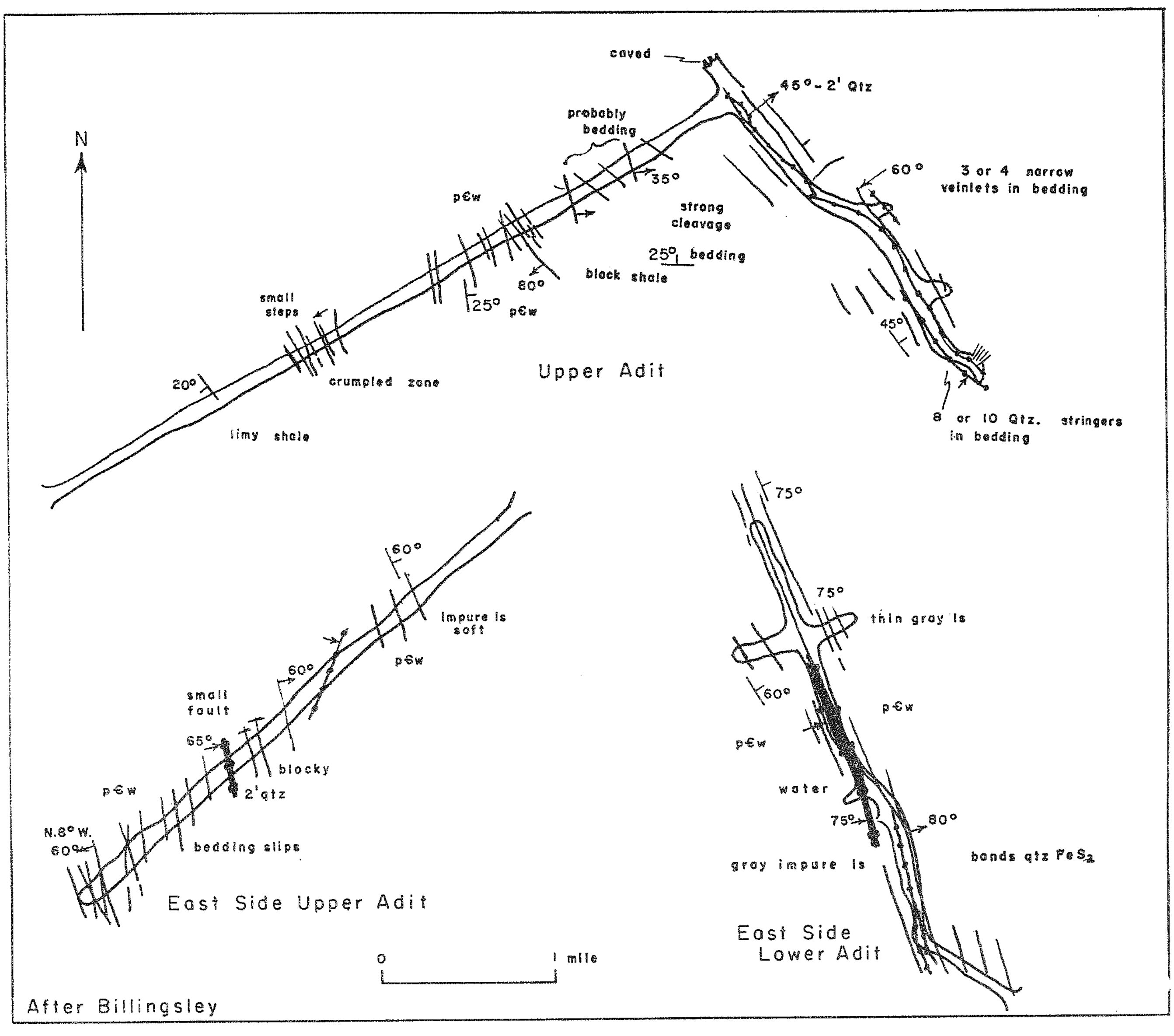


Figure 19.—East side Shaughnessy Hill group, Glacier Silver-Lead (formerly Lukens-Hazel, Hazel T.), N½ sec. 5, T. 29 N., R. 31 W., Libby district. (After Billingsley, 1915.)

Two veins, the west vein and east vein, occur in a shear zone, which strikes N. 20° W. and dips 45° to 60° NE. The ore bodies pitch to the southeast and are 400 to 440 feet apart on the third level. On surface the veins are about 800 feet apart. Gibson (1948, p. 112) reported:

> "The west vein, which has thus far been the more productive, has been explored for 2,000 feet along the strike. It is 2 to 10 feet thick and consists of sheared quartz containing variable amounts of pyrite, galena, sphalerite, and carbonate, named in order of abundance. In the country rock near the principal vein are small quartz veins of different thicknesses and attitudes, some of which occupy faults of small displacement. Some of these fault veins contain only barren quartz, whereas others contain small quantities of the same sulfides as are found in the larger vein. Movements along these veins have offset the large vein a few feet in some places.
>
> "The east vein is similar in many respects to the west vein, though it has not been so extensively developed. It varies in thickness from a few inches to 10 feet and consists predominantly of sheared quartz containing the same sulfides that occur in the west vein. A little scheelite has been found in the east vein.
>
> "In both veins quartz and pyrite, which were deposited early, have been crushed and brecciated by subsequent movement along the veins. A second generation of quartz, pyrite, and other minerals was then deposited."

Some ore was treated at the mill for shipment to the smelter during 1930. Two shipments of concentrates assayed 47.4 and 49.8 percent lead, 1.74 and 2.61 ounces gold, and 60.8 and 84.9 ounces silver a ton.

The Snowshoe fault follows the faulted axial trace of an anticline from a point south of Ramsey Creek to Leigh Creek. Short segments of the axial trace lie west of the fault between the headwaters of Poorman Creek and the head of Cable Creek, just west of the fault in the upper reach of Leigh Creek, and a clearly defined continuation of the anticlinal axis parallels the east block of the fault between Deep Creek and Horse Creek. Here, a west-northwest fault (north block down) has displaced the fold axis eastward. There is a possibility that the Glacier Silver-Lead veins are the north continuation of the Snowshoe structure. Because the Lukens-Hazel ore shoot rakes southeast, that segment of the Snowshoe fault on the south side of Horse Creek should be investigated for metallic minerals.

VICTOR-EMPIRE

The Victor-Empire property is at the end of the Granite Creek road on the north side of Granite Creek about 12 miles southwest of Libby. The property has been identified in reports as the Victor-Empire Mining and Milling Company, New Victor-Empire Mining and Milling Company, and the Victor Gold Mining Company, all of which had company offices in the Peyton Building, Spokane, between 1928 and 1937. Development includes a 2,000-foot drift on the Snowshoe fault and a short drift on a branching fault in Ravalli sedimentary rock. Some diamond drilling is reported to have been done northward from the face of the 2,000-foot drift. Development work in 1908 was reported in Mineral Resources (1908, p. 450), and Walsh and Orem (1912) described a 1,350-foot tunnel cutting commercial lead-silver ore. In 1936 the property was idle and consisted of 11 claims. In 1937 (Mines Register) the property was reported as consisting of 12 claims amounting to 200 acres. The property has been inactive since at least 1940.

An adit striking N. 51° W. for 50 feet intersects the nearly vertical Snowshoe fault and continues between N. 7° W. and N. 15° W. for 1,300 feet. Gibson (1948) reported that the drift continues for another 700 feet but was inaccessible at the time of his examination. The Snowshoe fault zone, here 2 to 5 feet wide, contains pyrite, pyrrhotite, and galena within quartz, as small irregular streaks or in part disseminated within the gouge and shattered wall rock; the sulfide mineralization extends into country rock bounding the fault zone. East of the fault is light-gray and white quartzite and sandstone of the Ravalli Formation, and west of the fault the wall rock is calcareous gray argillite and calcareous quartzitic argillite of the Wallace Formation. In some localities adjacent to the fault the wall-rock minerals have been partly replaced by tremolite, zoisite, and sphene. The mineral assemblage is commonly formed by metamorphism of sedimentary rocks and may therefore indicate the near presence of an igneous mass below surface.

At about 1,100 feet north from the portal of the adit a steeply dipping branch fault in Ravalli sedimentary rock was drifted on a short distance. Gibson (1948) reported the gouge and breccia zone as 30 inches thick and containing no more mineralization than the Snowshoe fault zone. This split may correspond to the east vein at the Lukens-Hazel mine.

A horizontal diamond drill hole from the face of the adit in a direction slightly north of east is reported to have intercepted gold-silver-lead ore at a distance of 940 feet. This report may have originated from a statement by the owner, reported in Montana Bureau of Mines and Geology Memoir 15 (Gilbert, 1935, p. 45), that a "diamond drill hole in 1924 cut a 4½-foot vein of gold ore assaying $290 per ton."

Logan Cresswell, Libby, and associates are reported to be the present owners of the property.

SILVER MOUNTAIN

The Silver Mountain group includes one patented claim, the Silver Crown (MS 5192) and three unpatented claims on the south side of Granite Creek. Inspector of Mines Report (Walsh and Orem, 1910) described a 500-foot tunnel on the vein. Only high-grade ore was mined in 1910, and several shipments of lead-silver ore were made. The mill was idle during this period. Ore was reported shipped to the Glacier Silver-Lead mill in 1926. In 1936 the property was under lease. A mill was erected but operated only for a short period in the 1940's; most of the milling equipment was removed prior to 1964. The present owner of the property is reported to be L. J. Brown of Libby. Logan Cresswell of Libby reported that some concentrates were shipped from the property during the 1940's.

This group is developed by three adits (now inaccessible), one above the other. An aerial tramway was used to transfer ore from the upper adits to the mill; this tramway was still standing but in poor condition in 1959.

According to Gibson (1948, p. 113) the lowest adit, now caved at the portal, is on the Snowshoe fault and follows the fault in a S. 3° W. direction. He stated:

> "The wall rock on the west is light-colored calcareous shale of the Wallace Formation, dipping westward; that on the east side of the fault is light-gray quartzite of the Ravalli Formation, dipping eastward. The Snowshoe fault, which is here about vertical, consists of breccia, gouge, small horses of country rock and vein quartz. Its average width is about 3 feet, but in places it is as much as 6 feet wide. Pyrite, arsenopyrite, galena, sphalerite, with less chalcopyrite and pyrrhotite, occur in streaks, bands, and disseminated grains in the quartz, mostly near the walls of the fault zone. A little carbonate and sericite are present. Diopside and actinolite have replaced the wall rock near the fault to a slight extent. Flat-lying to steeply dipping quartz veins as much as 20 inches in thickness branch from the main vein and penetrate the country rock, but they are not rich enough to follow. In many places the quartz is sheeted, and it there contains sulfides. Shearing continued or was repeated after the deposition of the pyrite, for the microscope shows that scattered pyrite was partly replaced by quartz, carbonate, and sulfides."

Ore similar to that in the lower adit was seen on dumps of the two upper adits. Gibson (1948) credited the property with one 22-ton shipment of concentrates from the lower adit. Selected specimens assayed by Gibson ran 8 to 18 percent lead, 8 to 21 ounces silver, and 0.4 to 1.2 ounces gold a ton.

Study of aerial photos suggests that the upper adits are on the Snowshoe fault, and the lower adit is on a parallel mineralized structure, which may correlate with the branching fault in Ravalli sedimentary rock in the adit drift of the Victor-Empire.

GRANITE CREEK

The Granite Creek Mining Company (formerly Mountain Rose) property consists of 10 claims located in 1936 on the south side of Granite Creek half a mile east of the Snowshoe fault. Gibson (1948) described surface installations in 1930 as including an aerial tram, connecting the adit and the camp on Granite Creek, blacksmith shop, and cabins. In 1936 four men were employed in development work consisting of driving a lower adit to intersect a large vein. Some shipments of ore had been made from the property prior to 1936. The property was inactive in 1964.

Development includes a principal adit trending S. 14° E. for 98 feet along Ravalli quartzite bedding, which dips 62° NE. At a distance of 88 feet from the portal a 770-foot crosscut has been run S. 50° W. to S. 70° W. to intersect northwest-striking quartz-sulfide veins. The veins occupy bedding faults, although in places they cut bedding at small angles. The veins are 1 to 12 inches thick and in places contain as much as 2½ inches of sulfides. Vein minerals are pyrite, galena, sphalerite, and lesser amounts of pyrrhotite and chalcopyrite. Sericite and carbonate are present as gangue minerals. Some postmineral movement has occurred along fault planes (Gibson, 1948).

BIG SKY

The Big Sky property, formerly the Montana Silver-Lead Mining Company property, was relocated in 1955 by Blaze Echo, Inis Herrig, and Clive Roark, who staked two claims Big Sky No.

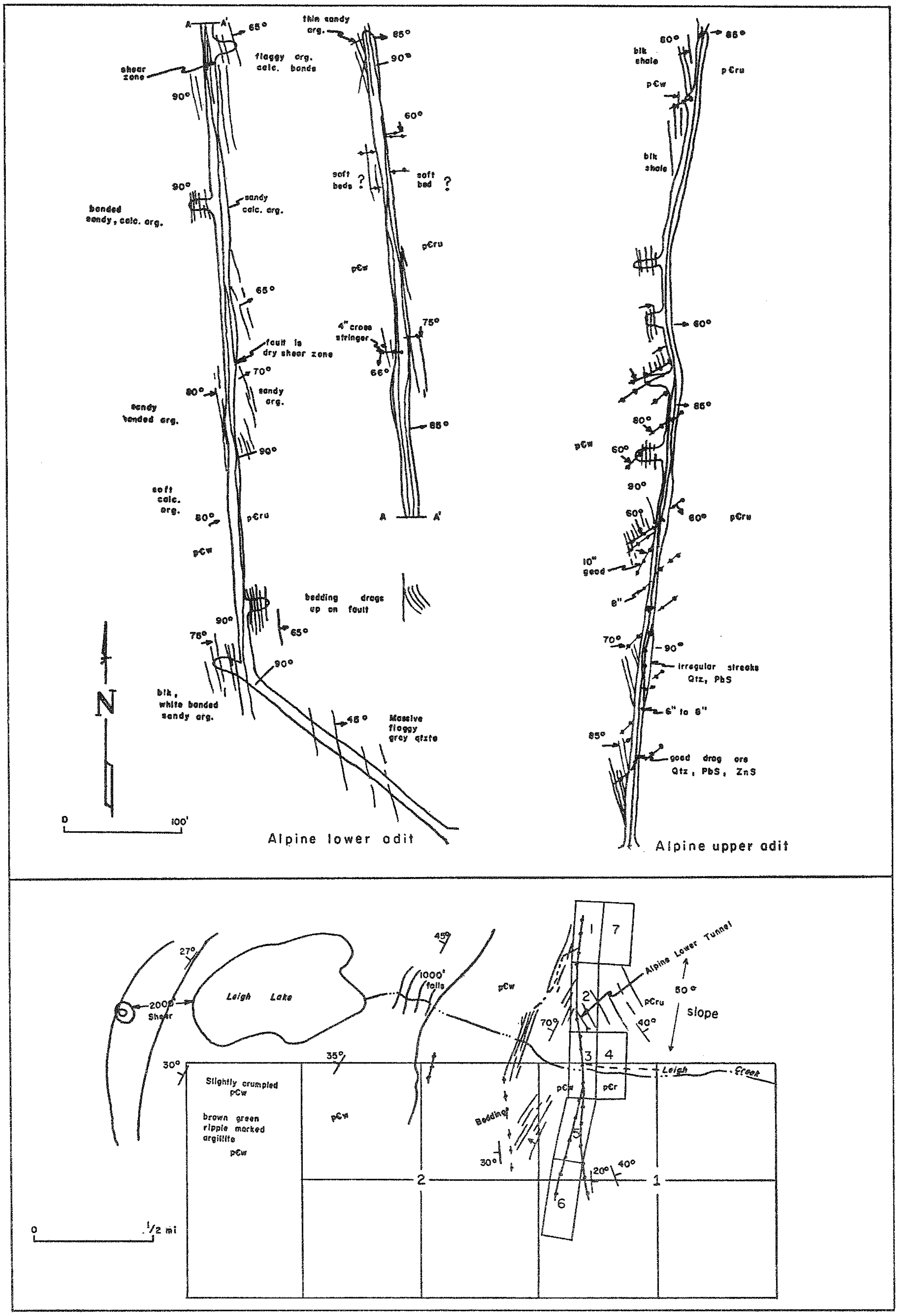


Figure 20.—Claim map and mine map of Big Sky property, Snowshoe fault area, Libby district. (After Billingsley, 1915.)

1 and 2. The property is located on the north side of Leigh Creek and originally included seven unpatented claims, five of which were staked on the Snowshoe fault (Fig. 20).

Development work consists of two accessible adits north of Leigh Creek (Fig. 20). The lower adit is 1,200 feet long and the upper adit, which follows the Snowshoe fault, is 700 feet long. Country rock is strongly sheared on both sides of the fault, which is as much as 6 feet wide and almost vertical. The fault strikes N. 5° W. (lower adit) to N. 5° E. (upper adit). Gray arenaceous and calcareous argillite and brown-red siliceous limestone (Wallace Formation) lie west of the fault, and gray argillite and white quartzite (Ravalli Formation) crop out east of the fault. Adjacent to the fault the Wallace beds strike north and dip 80° E. to vertical, but several hundred feet west, they dip 68° W. Ravalli beds to the east strike N. 20° to 25° W. and dip 45° to 65° E. The relative fault movement is up on the east and down on the west side.

Sparse quartz veins as much as 8 inches wide occupy the faults and penetrate the adjacent wall rock. These veins contain masses and irregular streaks of galena, minor sphalerite and pyrite, and sparse chalcopyrite, arsenopyrite, and pyrrhotite. Gangue minerals besides quartz are calcite and ankerite. Disseminated particles and veins of sulfide extend into the hanging wall and footwall of the fault. Secondary anglesite, cerussite, copper carbonates, and limonite are present but sparse in the oxidized parts of the veins. Some scheelite was discovered in the lower adit, and on the basis of this mineral showing, the property was leased to a Canadian syndicate for a period of 18 months.

Gibson (1948) analyzed a selected specimen lean in sulfides, which assayed 12.4 ounces silver and 0.01 ounce gold.

GRIZZLY

The Grizzly property was formerly the Missouri group and was identified by Billingsley (1915) as the McDonald property (Fig. 21). The Missouri group consisted of seven unpatented claims on the north side of Leigh Creek about 2 miles above its confluence with Cherry Creek and 1½ miles east of the Snowshoe fault. The property was relocated in 1955 by Blaze Echo and Inis Herrig, who staked two claims, Grizzly No. 1 and 3. No production has been reported from the property.

Development includes three short adits, totaling 213 linear feet, at altitudes of 3,600 to 4,400 feet (Fig. 22). Nearly vertical quartz veins in a shear zone trending about N. 45° W. cut thin-bedded to massive white Ravalli quartzite stained with iron oxide. Bedding strikes N. 10° to 30° W. and dips 30° to 45° NE.

Gibson (1948, p. 119) stated:

"The sulfides seen in the adits and on the dumps are galena, pyrite, arsenopyrite, and chalcopyrite. Parts of the vein are more or less oxidized, pyrite and arsenopyrite being replaced by limonite and galena by anglesite. The most abundant gangue mineral is quartz, although ankerite, altering to iron and manganese oxides, is conspicuous in one of the upper adits. As may be seen in polished sections, arsenopyrite was one of the first of the primary metallic minerals to be deposited; it is replaced in part by galena, chalcopyrite, and pyrite. Though most of the quartz is earlier than the sulfides, tiny veinlets of later quartz cut through shattered pyrite and arsenopyrite."

SILVER CABLE

The Silver Cable prospect is on the south side of Cable Creek at an altitude of 5,500 feet. The prospect is developed by four adits (inaccessible) on the Snowshoe fault. Hunter and Byrne (1897) reported that the Cable Mining Company employed eight miners and two men on surface. The mine was active during 1901 and 1902 and 1905 to 1906, but no production has been reported from the property, which has been inactive for many years. Two patented claims, the Silver Cable (MS 4023) and Silver Cable Fraction (MS 4024) constitute the group. Gilbert (1935, p. 45) reported that at the time of his visit the property comprised five patented claims. Near the turn

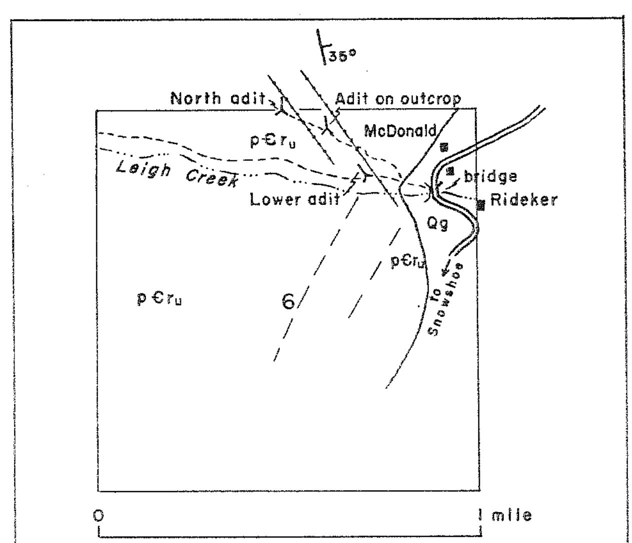


Figure 21.—Sketch of Grizzly property, formerly Missouri group. (After Billingsley, 1915.)

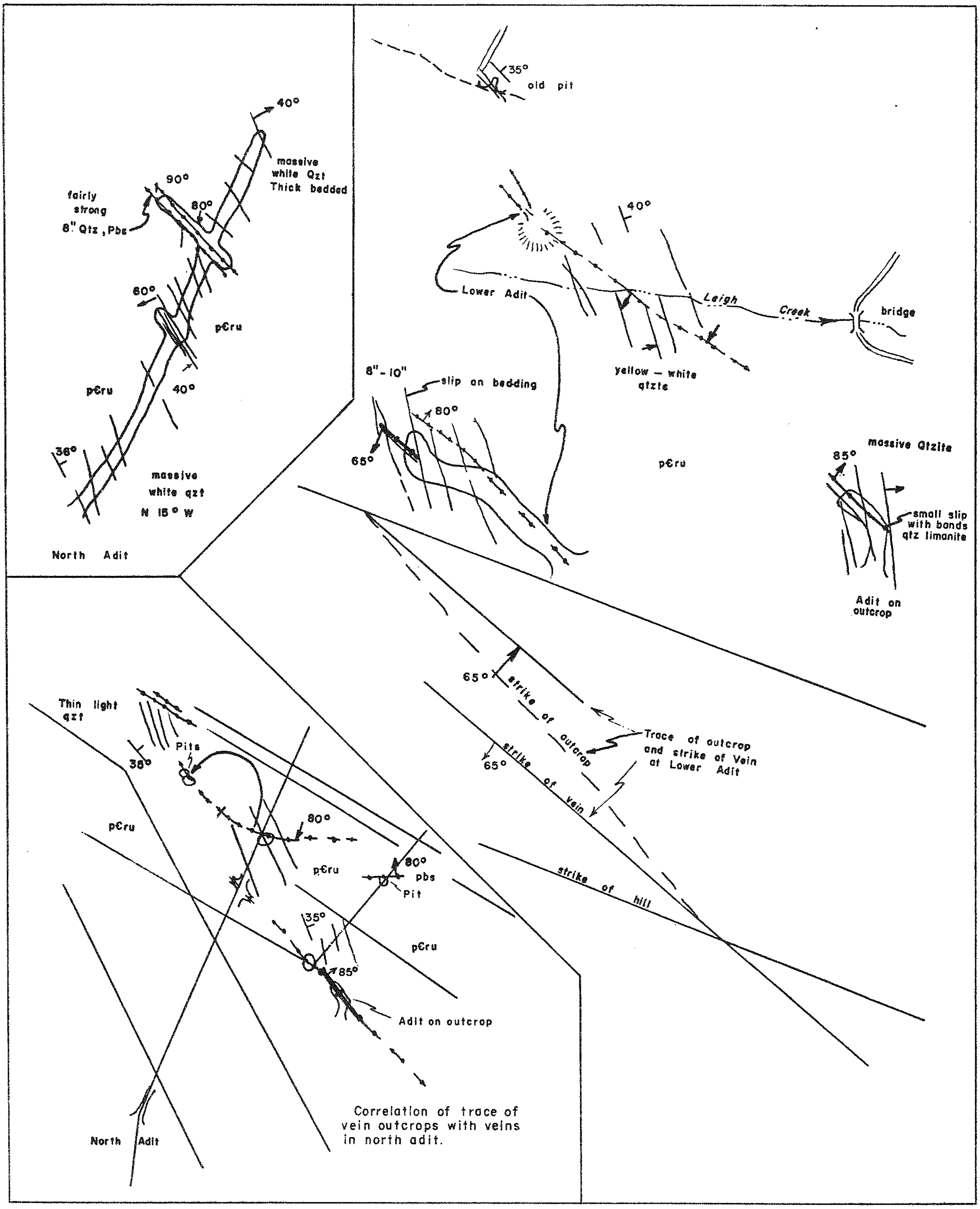


Figure 22.—Lower tunnel and north tunnel of the Grizzly property, Libby district. (After Billingsley, 1915.)

of the century a 50-ton concentrator was erected at the base of the slope on Cable Creek and was served by a 3,000-foot gravity tram; the mill never operated, owing to insufficient ore. This building was recently removed to make way for a logging road. A cat road has been constructed to within a quarter of a mile of the workings.

The property was idle in 1934, at which time the patented claims were owned by I. M. Hart of Kalispell.

Development work includes three adits, now inaccessible, one above the other on the Snowshoe fault, which here is about 4 feet wide, strikes slightly west of north, and dips 80° E. The fault encloses a 3-foot quartz vein on which one adit had been reportedly driven 75 feet southward. Another adit is reported to be 325 feet in length. On the dump of the center adit was a 3- to 4-foot boulder from the mineralized zone; it contained galena, pyrite, and minor sphalerite and chalcopyrite as masses and disseminated particles throughout the quartz and carbonate gangue. If the boulder is representative, a continuous mineralized vein would contain sufficient metallic minerals to constitute mill-grade ore. Vein material on dumps includes quartz, pyrite, and carbonate rock, and less abundant galena and pyrrhotite.

Here the Snowshoe fault separates dark-gray argillite and argillaceous quartzite of the Prichard Formation on the east from light-gray quartzite and quartzitic argillite of the Ravalli Formation on the west. Prichard beds strike N. 20° W. and dip 38° to 50° NE. Ravalli strata have a parallel strike, and dip 38° to 40° NE. A segment of the axial trace of an anticline is about three-eighths of a mile west of the property.

STATESMAN

The Statesman prospect (inactive) is on the south side of Poorman Creek at an altitude of 6,300 feet.

A 3-foot fault zone, exposed in open cuts, contains quartz veins as much as 7 inches thick flecked with sparse galena and arsenopyrite and very sparse pyrite, pyrrhotite, sphalerite, and chalcopyrite. The fault strikes N. 8° W., dips 80° NE, and is believed to be parallel to the Snowshoe fault, which is several hundred feet to the west. About 40 feet west of the open cuts is a quartz vein 12 inches wide. The prospect is in Prichard argillite, which strikes N. 10° W. and dips 25° to 40° NE.

HALFMOON

Approximately five-eighths of a mile east of the Snowshoe fault and 600 feet south of the Poorman Creek-Cable Creek divide is the Halfmoon unpatented claim. It was relocated by Austin and Wallace Monk, Kalispell, on September 4, 1963, and relocated by others in August 1964. Development work amounts to a 10-foot tunnel and two pits. The following information on the property was obtained from Austin Monk.

The short tunnel exposes a 22- to 24-inch nearly vertical vein parallel to the Snowshoe fault. The vein contains galena, cerussite, quartz, and abundant iron oxides. Galena forms pods in the vein. A rusty-brown earthy specimen of cerussite and iron oxides assayed more than 50 percent lead. Selected grab samples of galena-cerussite assayed 54 percent lead. The tunnel and other workings are in the oxidized zone.

The property has not produced.

HERBERT

The Herbert group of 10 claims lies on the north slope, near the head of Prospect Creek. Gibson (1948, p. 90) described the property as follows:

> "The country rock, which is gray sericitic sandy shale and sericitic sandstone of the Wallace Formation, is sharply folded, and the beds dip steeply to the west and to the east. Near the top of the ridge several shallow trenches have disclosed a group of narrow vertical quartz veins in a zone about 20 feet wide, which trends northwest, parallel to a fault seen in an adit lower on the hill. The quartz veins and intervening rock contain tiny pyrite grains, or vuggy iron-stained cavities where sulfide has weathered out. A little gold can always be panned from the oxidized rock containing these quartz veins. When the property was visited in 1934, 300 feet of work had been done in an adit about 300 feet above the camp on Prospect Creek. Two steeply dipping northwestward-trending faults were seen in this adit, but the lode had not been encountered."

REMP

On the north slope of Cedar Creek about half a mile north of Lower Cedar Lake is the Remp prospect. Several short adits explore a quartz vein striking N. 45° W. and dipping 50° SW. Sulfide minerals from dumps indicate that the quartz vein contains tetrahedrite, galena, pyrite, and pyrrhotite. The workings are in gray Wallace limestone, which strikes north to northwest and dips 8° to 20° NE.

TROY DISTRICT

SNOWSTORM

The Snowstorm property, formerly known as the B. and B., has been the largest producer in the Libby quadrangle. It is on the south side of Callahan Creek, about 5 miles southwest of Troy. Two of the patented claims are the Banner (MS 8112) and the Bangle (MS 8113). As many as 60 unpatented claims are reported to have been located by W. A. McCaffery, who consolidated the Snowstorm and Big Eight properties after acquiring the claims about 1931.

MacDonald (1906) visited the Troy mining district in 1905 and referred to the Snowstorm as the B. and B. It had previously shipped some ore, although at the time of his visit the property was inactive. In 1911 the B. and B. property was credited with shipments of development ore (Mineral Resources, p. 632). In 1912 the B. and B. was acquired by the Greenough Investment Company. In 1913 the B. and B. and Big Eight mines were opened for production of zinc (Mineral Resources, p. 606).

The Snowstorm was operated by the Snowstorm Mines Consolidated Company from 1918 to the late twenties. During the period of its greatest productivity, 1918 to 1926, the Snowstorm Mines Consolidated Company employed between 250 and 300 men and produced 202,000 tons of ore valued at $1,516,000. In 1931 the property was controlled by the Troy Mines Company. In the 30's it was acquired by the late W. A. McCaffery of Chicago, and in 1964 it was held by the McCaffery estate.

Gibson (1948) visited the mine in 1931, at which time both the Snowstorm and Big Eight mines were idle and only the upper adits of the Snowstorm were accessible (Fig. 23). Gibson reported production from the Snowstorm amounting to at least $4 million in lead, zinc, gold, and silver; ore reserves (including possible ore) amounted to 207,000 tons, mostly in the workings above the sixth level now inaccessible. The mine was inactive for at least 35 years, but in 1965 the Snowstorm mine and adjacent properties in the Troy district were leased to the Missouri-Montana Mining Company. Some zinc ore was shipped to the Bunker Hill concentrator at Kellogg, Idaho (Minerals Yearbook, 1965).

In 1917 a 350-ton mill was constructed to mill ore from the Snowstorm mine and custom ore from the surrounding districts. In May 1927, the mill was destroyed by fire and mine production thereafter was negligible. It is reported that the precious-metal content in the ores was sufficient to pay for milling expenses.

Development work includes several adits at different altitudes, the lowest tunnel having served as a haulage level for ore mined from upper levels. Adits 6 and 7, 1,900 and 2,350 feet in length respectively, were mapped by Gibson (1948, Fig 5). Two shafts from the lower tunnel are reported to have been sunk to depths of 125 feet and 600 feet. Total length of adits is reported to be 10,000 feet; 500 feet of drifts, 3,500 feet of crosscuts, and 1,100 feet of raises make up the additional development.

Replacement veins several inches to 8 feet wide contain sulfide minerals, which in order of decreasing abundance are galena, sphalerite, pyrrhotite, pyrite, chalcopyrite, and arsenopyrite, in a gangue of quartz, calcite, chlorite, amphibole, and biotite. The veins are enclosed in the Snowstorm dike, which strikes N. 25° to 30° W. and dips 75° to 80° SW. Gibson mapped this coarse-grained mafic dike as 54 feet wide in Adit 6 and as two segments 44 feet and 17 feet wide and

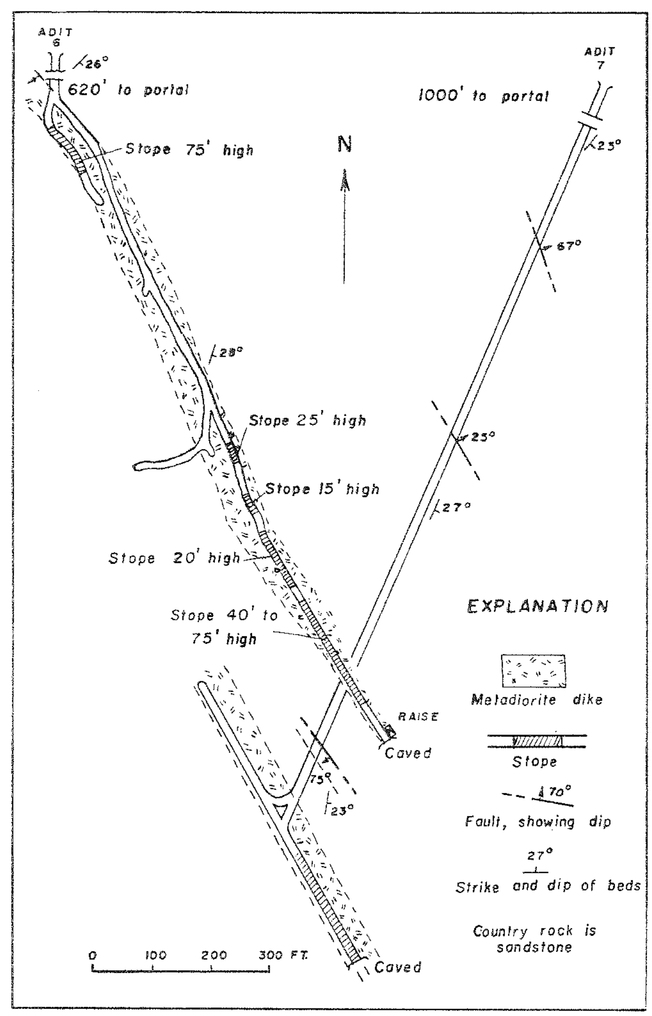


Figure 23.—Geologic map of Adits 6 and 7, Snowstorm mine, Troy district. (After Gibson, 1948.)

about 70 feet apart in Adit 7. Prichard wall rock enclosing the dike is hard fine-grained sericitic quartzite containing much biotite and chlorite near the contact with the dike. Pyrrhotite, pyrite, sericite, and biotite have been introduced into both the dike and the Prichard rocks, pyrite being disseminated in the Prichard Formation as far as 500 feet from the dike. The trend of the vein approximates that of the dike, but the vein dips more steeply to the southwest. The Leonia fault is a short distance east of the property.

Accessible sections of Adits 6 and 7 have been stoped above the sill for distances of 20 to 260 feet, to a height of 100 feet, and to a width of 10 feet. Some sections of the vein were barren of metallic minerals or contained only sparse sulfides, and in Adit 6 these unproductive portions were left as pillars.

The paragenetic sequence of vein minerals (Gibson, 1948, p. 99) is amphibole and garnet followed by quartz, chlorite, biotite, calcite, pyrite, sphalerite, arsenopyrite, pyrrhotite, chalcopyrite, and galena. Gibson reported some supergene pyrite in the ore.

In the footwall of the dike, about 620 feet from the portal of Adit 6, is a northwest-striking fault that dips 70° SW. A lean vein within the fault has produced breccia, indicating some post-ore fracturing. Near the hanging-wall contact of the dike, another vein, which attains a width of 6 feet and consists chiefly of gangue minerals, has been exposed by a drift for a distance of 180 feet. This vein parallels the footwall fault and has been stoped for a distance of 100 feet and to a height of 75 feet.

In Adit 7 several northwest faults offset Prichard strata and dip northeast or southwest. They contain a few inches to 2 feet of breccia and gouge, but Gibson observed no metallic minerals in these fissures.

Country rock in the area is banded gray-blue argillite and gray fine-grained sericitic quartzite and sandstone of the Prichard Formation. Beds strike northwest and dip moderately to the east.

BIG EIGHT

The Big Eight property (4 patented and 2 unpatented claims) is directly north of the Snowstorm claims. Workings are on both sides of Callahan Creek. In 1906, the property consisted of three claims owned by the Silver Torrent Mining Company. The lowest tunnel intersected the vein 600 feet below the surface, and an ore body was opened for a distance greater than 300 feet. During 1906 a 450-foot crosscut tunnel was driven; additional development consisted of 350 feet of drifting, a 75-foot winze, and some drifting east from the base of the winze. Four carloads of ore were shipped each month to Germany via Seattle for treatment (Walsh and Orem, 1906).

During 1909 to 1910, a tunnel was extended 500 feet. In 1912 the Big Eight was leased to R. C. McCaffery. The property was visited by MacDonald (1906), who described the Big Eight and Snowstorm properties as on the same fissure vein or on two parallel slightly separated fissure veins having similar mineral characteristics. At the time of MacDonald's visit the Big Eight was leased to Spokane interests, and 150 tons of ore was stockpiled at the property. The Big Eight was consolidated with the Snowstorm property by W. A. McCaffery, and both are now owned by the McCaffery estate.

The property has been idle for more than 20 years. Total production between 1912 and 1928 amounted to more than 6,000 tons of zinc-lead ore containing some copper, gold, and silver. In 1944 this property was leased to the Chance Mining Company, who shipped 30 tons of zinc-lead ore to the East Helena smelter and 267 tons of ore to Utah to be treated.

The property is developed by several adits; two are north of Callahan Creek and one is south of the creek. The south adit and the lower north adit trend S. 22° E. and N. 23° W., respectively. The dike forms one wall and Prichard argillite and quartzite the other in both adits. Gibson (1948) reported an aggregate length of at least 1,000 feet for a third north adit, about 100 feet above the lower tunnel. The upper tunnel was accessible in 1965 (personal communication, John Bowsher). About 450 feet of crosscuts and two winzes, totaling 140 feet, complete the workings.

In the Big Eight mine the major vein is as much as 8 feet wide, and follows the west wall of a mafic dike (Snowstorm dike) on a bearing of N. 22° W.; sections of the vein are either vertical or dip steeply southwest. The vein is exposed for a distance of 500 feet. MacDonald (1906, p. 48) described a small vein of massive galena 200 feet east of the main vein. Gibson (1948, p. 100) described a vein, parallel to and east of the main vein, that had been stoped to some extent.

Ore minerals consist of sphalerite and less abundant galena, pyrrhotite, chalcopyrite, and pyrite. A trace of cobalt has been reported. Sulfide distribution is irregular, although ore bodies of considerable size occur. Gangue minerals in the vein include quartz, calcite, actinolite, chlorite, and garnet, associated with masses of country rock. Magnetite in vein material is very subordinate. Sulfide minerals are most abundant where chlorite and actinolite occur.

Gibson (1948, p. 100) described a post-ore fault that strikes northwest and dips 25° NE, which displaced the major vein several feet northwest, and which may be in part be a bedding fault.

GIANT SUNRISE

The Giant Sunrise property, formerly known as the Montana Sunrise, consists of nineteen unpatented claims and a millsite on the northeast slope of Grouse Mountain, about 5 miles south of Troy (Fig. 24). The property was relocated by Wallace Litchfield of Troy from a group of 23 claims formerly held by Jim Bussard. Tom Schessler, U. S. Forest Service examiner, visited the property in 1958 and supplied some of the following data.

Development work consists of five adits, four of which were accessible in 1958, on veins in a dark-gray to black dike composed of plagioclase, biotite, and quartz in various proportions, and containing carbonate, sericite, chlorite, ilmenite, and sphene. Adits 4, 6, 7, and 10 are respectively 255 feet, 500 feet, 1,100 feet, and 6,000 feet long; No. 7 and 10 tunnels trend about S. 40° E. from portals in sec. 3 (Fig. 24). A caved adit (No. 5?) was driven on an 18-inch quartz vein in a draw. A lead-zinc ore body was discovered in 1928 (Mineral Resources, p. 593).

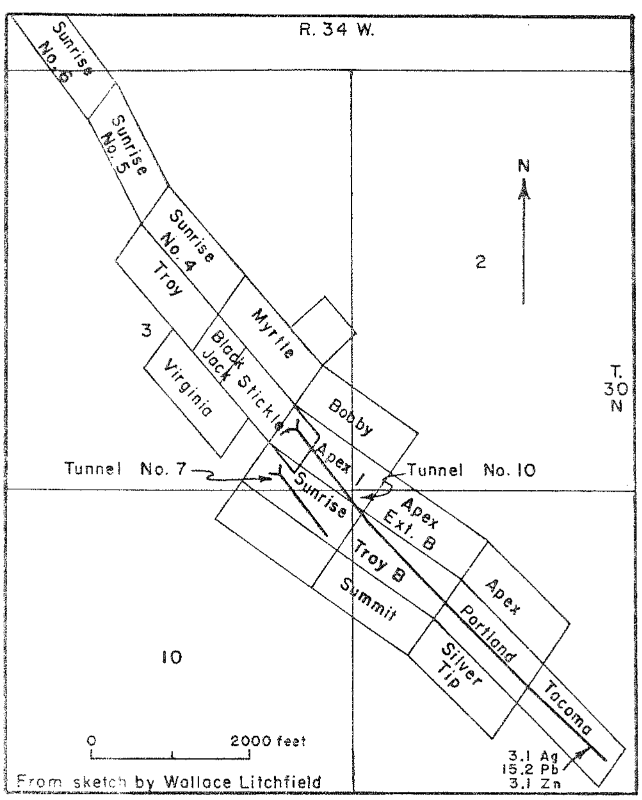


Figure 24.—**Claim map of Giant Sunrise property, Troy district.**

The veins, which strike N. 35° to 45° W. and dip steeply northeast, are in sheared sections of the dike or at the contact of the dike with the sedimentary rock. The dike, which strikes northwest, intrudes argillite and quartzite of the Prichard Formation, which strikes about N. 25° W. and dips 50° SW. Sulfide minerals consist of sphalerite, pyrrhotite, galena, chalcopyrite, and pyrite in a gangue of quartz, calcite, chlorite, and less common sericite. Ilmenite is scarce. The veins are as much as 3 feet thick, and disseminated sulfides and veinlets extend as much as 20 feet from the veins into adjacent Prichard wall rock. Postmineral movement along bedding planes in the sedimentary rock has offset the veins and the dike. Ore on No. 7 dump is dark-brown sphalerite and galena in white quartz gangue.

Gibson (1948, p. 102) reported that sulfide minerals were most abundant in the higher adits (No. 4 and 6) and that mill heads from the mine contained 6 percent lead, 8.50 percent zinc, and 1.20 ounces silver a ton. Lead concentrates from a 200-ton mill erected in 1934 containing 72.20 percent lead and 16 ounces silver; zinc concentrates yielded 50.40 percent zinc, 4.30 percent lead, and 1.70 ounces silver a ton. The mill was active in 1935 to 1936, employing as many as 15 men. Litchfield, the manager at that time, stated that 12 to 40 men were employed at the property. The mill was dismantled some time prior to 1958, but the property was active in 1939.

Liberty Metals crosscut Adit 11 has its portal on the Giant Sunrise claim and was driven southwest in the Prichard Formation for a distance of 1,800 feet to intersect veins on the Little Spokane, Silver Strike, and Cabinet Queen claims on the Grouse Mountain dike.

A sample of vein material collected by Tom Schessler near the face of Adit 10 assayed 15.20 percent lead, 3.10 percent zinc, and 3.10 ounces silver a ton.

GROUSE MOUNTAIN

The Grouse Mountain property, discovered and first prospected in 1892, lies on the west side of Grouse Mountain. It was being developed when Gibson examined the property in 1932, and he reported (1948, p. 102) that the group included 27 unpatented claims and that surface installations included several good cabins, a blacksmith shop, and an ore bin. In 1958 the mine was operating and was then owned by Lawrence Lemier of Libby, who had recently relocated several claims of the original Grouse Mountain group. Four crosscut adits and 3,000 feet of drifting explore the Grouse Mountain dike and adjacent ground.

One crosscut adit in Prichard strata driven in a northerly direction intercepted the Grouse Mountain basic dike at a distance of 1,040 feet from the portal. The dike strikes northwest and and is 145 feet wide; its northeast contact is a fault. Drifts northwest and southeast from the crosscut have explored lenticular and faulted veins in sheared rock. The veins contain quartz, calcite, galena, sphalerite, pyrrhotite, arsenopyrite, pyrite, and chalcopyrite. Chlorite and supergene marcasite are scarce. According to Gibson (1948, p. 103), the sequence of sulfide mineral deposition was arsenopyrite, pyrite, pyrrhotite, sphalerite, and galena. The ore contains both gold and silver. Veins attain a maximum width of 18 inches, but average about 10 or 12 inches wide, and are parallel to the trend of the dike. The most abundant valuable vein minerals are galena and sphalerite. Ore bodies are discontinuous and are disturbed by postmineral faulting.

Gibson (1948, p. 103) reported that the dike is thoroughly altered at both contacts to fine-grained homogeneous-looking rock in which only biotite is easily identified by inspection. The chief minerals identified in thin section were chlorite, sericite, and carbonate.

LIBERTY METALS

The Liberty Metals property is on Iron Creek, 6 miles south of Troy. The Silver Strike Mining Company, a former owner, was reported to have been absorbed by Liberty Metals in 1934. Development work was reported for the years 1923, 1926, and 1928 to 1930, but only a small shipment of ore had been mined from the property prior to 1934. The property was inactive in 1936, but was expected to resume operation soon. Minerals Yearbook lists production from the property in 1938. In 1958 the principal adit was accessible but a 100-ton mill erected in 1934 had been dismantled. The property comprises eight patented and nine unpatented claims, and in 1958 it was being managed by the late Elizabeth Powers for owners reported to live in Kansas City, Missouri.

Development work consists of three adits and a shaft totaling 2,800 feet of underground workings. Gilbert (1948, p. 44) described development amounting to 2,600 feet of drifts and a 207-foot shaft. Principal development is a main adit driven southeast closely following the contact between Prichard strata and a basic sill. This adit extends through the Leonia fault into Wallace strata east of the fault. The Leonia fault here strikes about north, is vertical, and has a crushed zone 20 feet wide. Several crosscuts have been driven from the principal adit to search for ore.

Gibson (1948, p. 105) reported as follows:

> "Most of the ore consists of galena, with less sphalerite and pyrite, in an abundant gangue of quartz and carbonate. The ore forms irregular small veins and replacement masses along joints and near irregular shear zones in quartzitic sandstone. All the ore seen in the quartzitic sandstone was near the sill contact, but none of the mine openings were extended very far into the Prichard rocks in search of ore. Horizontal drill holes driven into the sandstone near the northeastern contact of the sill revealed disseminated galena in patches or small veins between 6 and 28 feet from the contact. In addition to the ore in sandstone a smaller quantity occurs in the sill, where it forms very irregular veins and patches related to discontinuous shear zones. Quartz and carbonate are the most abundant vein minerals, and galena, sphalerite, pyrrhotite, pyrite, and chalcopyrite are rather scarce. The ore from the sill is said to be richer in gold, according to the assays, than that from the quartzite."

IRON MASK

The Iron Mask property consists of two patented claims and two patented fractions on the southwest slope of Grouse Mountain. The ore was discovered in 1892, and 200 tons had been shipped prior to Gibson's visit in 1931. Three carloads of ore were mined in 1930 (Gilbert, 1935, p. 43). In 1943 the Montana Mining and Milling Company leased the Iron Mask and Montana Morning properties and the 25-ton Giant Sunrise mill, and between July and November of 1943 produced 9 tons of lead concentrate and 23 tons of zinc concentrate. In 1957 the property was leased to J. L. Elby of Bonners Ferry, Idaho, by co-owners E. J. Powers of Troy and H. Seaford of Libby.

Irregular and discontinuous veins, one of which is reported to be 7 feet wide, in sheared and faulted sections of the Grouse Mountain dike have been explored by two 300-foot adits trending northwestward. The dike is at least 155 feet thick and strikes N. 40° W. and dips 60° NE. It cuts Prichard argillite and quartzite, which strike northwest and dip 55° to 65° SW. Postmineral shearing and faulting are evident within and parallel to the veins. Some shear zones are at the contacts of the veins and dike rock, but other shears cut across the veins.

Sulfide minerals present in the veins, in order of abundance are galena, sphalerite, arsenopyrite, pyrrhotite, pyrite, and chalcopyrite in a gangue of quartz, calcite, chlorite, and hornblende. Dike rock has been thoroughly altered, and the main constituents are sericite, chlorite, biotite, carbonate, and minerals of the epidote group.

SILVER KING

The Silver King property comprises three unpatented mining claims on the North Fork of Keeler Creek. Reported development work amounts to 850 feet of workings in seven short adits, which in the fall of 1957 were being reopened by Jim Lyle. Production from the mine during 1929 to 1930 was six carloads of lead-silver ore containing some zinc and a fraction of an ounce of gold.

Gibson (1948, p. 104) described the deposit as follows:

> "The lowest [adit] . . . which is at an altitude of 2,950 feet, trends N. 40° E., is 300 feet long, and has one crosscut driven on a fault zone on the southwest contact of the Silver King sill. There is little mineralization in the fault zone. The fault, which in part follows the bedding, strikes N. 55° W. and dips 50° SW.
>
> "In two other adits higher on the hill the same fault is exposed in crosscuts, where there are stopes that have yielded six cars of ore. Galena and quartz are the chief minerals, chalcopyrite and pyrite are scarce, and no sphalerite was seen in any of the specimens examined. The ore occurs in patches in the fault breccia, the ore-bearing part of which was nowhere much more than 2 feet wide in any of the stopes that were entered. The stopes are not far from the surface, and the fault has afforded a permeable channel for descending oxidizing waters, which have formed anglesite, cerussite, copper carbonates, covellite, and limonite in the ore."

The deposit is near the Ravalli-Prichard contact, which here strikes northwest and dips 45° to 55° SW.

Ore produced from the Silver King mine was reported to assay 12.3 ounces silver and 0.19 ounce gold a ton, 60.9 percent lead, and 1.0 percent zinc.

SILVER GROUSE

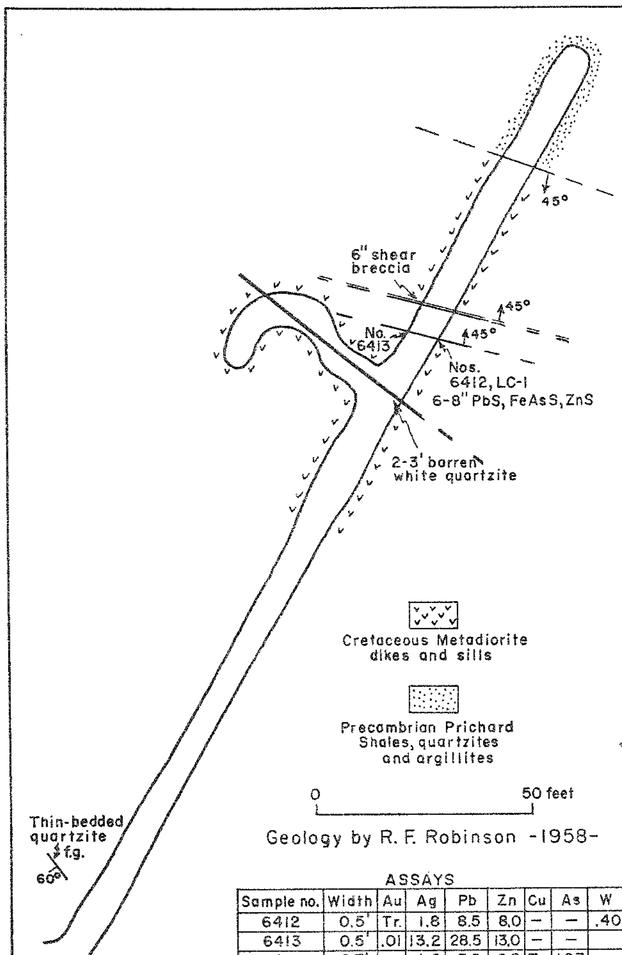
The Silver Grouse group of nine unpatented claims is on the northeast slope of Grouse Mountain at an altitude of 3,525 feet. The claims were relocated prior to 1958 and annual assessment work thereafter was performed by Wallace Litchfield. Several quartz veins in Ravalli quartzite are developed by a 311-foot adit and two shallow shafts.

The veins, ranging from 4 to 17 inches wide, strike N. 35° to 80° W. and dip about 45° NE. They occur in shear zones in quartzite. Vein minerals include quartz, pyrrhotite, chalcopyrite, pyrite, galena, and carbonate. The wall rock contains small amounts of disseminated sulfides and biotite. Some postmineral faults parallel the veins and dip northeast but others crosscut them and dip southwest. The latest movement is along the southwest-dipping structures.

Selected high-grade samples of galena were reported to have assayed 4 to 71 ounces silver a ton.

LAST CHANCE

The Last Chance property (formerly Little Spokane) is on the Grouse Mountain dike on the south slope of Grouse Mountain. It consists of two unpatented claims, Jack No. 1 and No. 2, owned by Elide and Albert Commellini of Spokane, Washington. No production from the property had been reported as of 1959.



ASSAYS

Sample no.	Width	Au	Ag	Pb	Zn	Cu	As	W
6412	0.5'	Tr.	1.8	8.5	8.0	–	–	.40
6413	0.5'	.01	13.2	28.5	13.0	–	–	
LC-1	0.7'	–	1.2	5.0	0.8	Tr.	1.97	

Figure 25.—Sketch of Last Chance No. 2 adit, Troy district.

At a distance of 150 feet from the portal (Fig. 25), the 240-foot crosscut adit trending N. 30° E. intersected a barren 2-foot quartz vein striking N. 50° W. A smaller vein, striking N. 75° W. and dipping 45° NE., was intersected at a distance of 165 feet from the portal. This vein contains massive sulfides, which in order of abundance are galena, sphalerite, arsenopyrite, and chalcopyrite in a gangue of quartz and carbonate rock. Gibson (1948, p. 108) reported galena partly altered to anglesite in the veins. Northeast of the veins are two nearly parallel northwest-trending faults; one dips 45° NE and the other dips 45° SW. The veins and faults are in the basic Grouse Mountain dike, which strikes northwestward. The dike cuts Prichard argillite and thin-bedded fine-grained quartzite, which strike N. 32° W. and dip 60° SW.

Two samples collected by R. F. Robinson from the sulfide vein, across a width of 0.5 foot, assayed respectively 8.5 and 28.5 percent lead, 8.0 and 13.0 percent zinc, 1.8 and 13.2 ounces silver, a trace and 0.01 ounce gold, and 0.40 percent tungsten. A channel sample collected by Tom Schessler assayed 5.0 percent lead, 0.80 percent zinc, 1.20 ounces silver, and a trace of copper.

MONTANA MORNING

The Montana Morning property is near the head of Iron Creek and is owned by John and Violet Molyneaux of Troy. The four unpatented claims (Fig. 26), relocated in 1946, are near the southeast end of the Snowstorm dike. In 1910 the company operating the property employed 25 men. The mine was developed by adits totaling 700 feet on the vein. Development in 1912 was described as two tunnels 700 and 350 feet in length on the vein (Walsh and Orem, 1910, 1912).

Workings accessible in 1958 consisted of a 350-foot adit, an 80-foot winze, and two short crosscuts on the vein on Montana Morning No. 2 claim, and a small open cut and shallow pit on Montana Morning No. 3 claim. Buildings included a blacksmith shop and ore bin.

The main vein, 2 to 2½ feet wide, strikes N. 10° to 20° W. and dips 80° to 85° NE. It is in the Snowstorm dike, which here is 15 feet wide. Smaller veins a few inches wide occupy fracture zones in the dike and in adjacent sedimentary rock. The dike and veins are in Prichard quartzite and argillite, which strike N. 25° W. and dip 50° SW. Galena, sphalerite, chalcopyrite, pyrite, and pyrrhotite are sparse in the carbonate and quartz gangue of the veins. Within small irregular shear zones in the Prichard rocks just east of the dike are patches of sulfides, which have been explored (Gibson, 1948, p. 110) by a raise and winze. Some ore was mined from stopes in the dike and treated at the Snowstorm mill.

HIAWATHA

The Hiawatha property is on the North Fork of Keeler Creek at an altitude of about 3,800 feet. It was reported (1958) that this prospect was relocated by the late Elizabeth Powers of Libby and Harvey Seaford of Troy.

An adit, started in the Grouse Mountain dike, was visited by Gibson (1948, p. 107) who report-

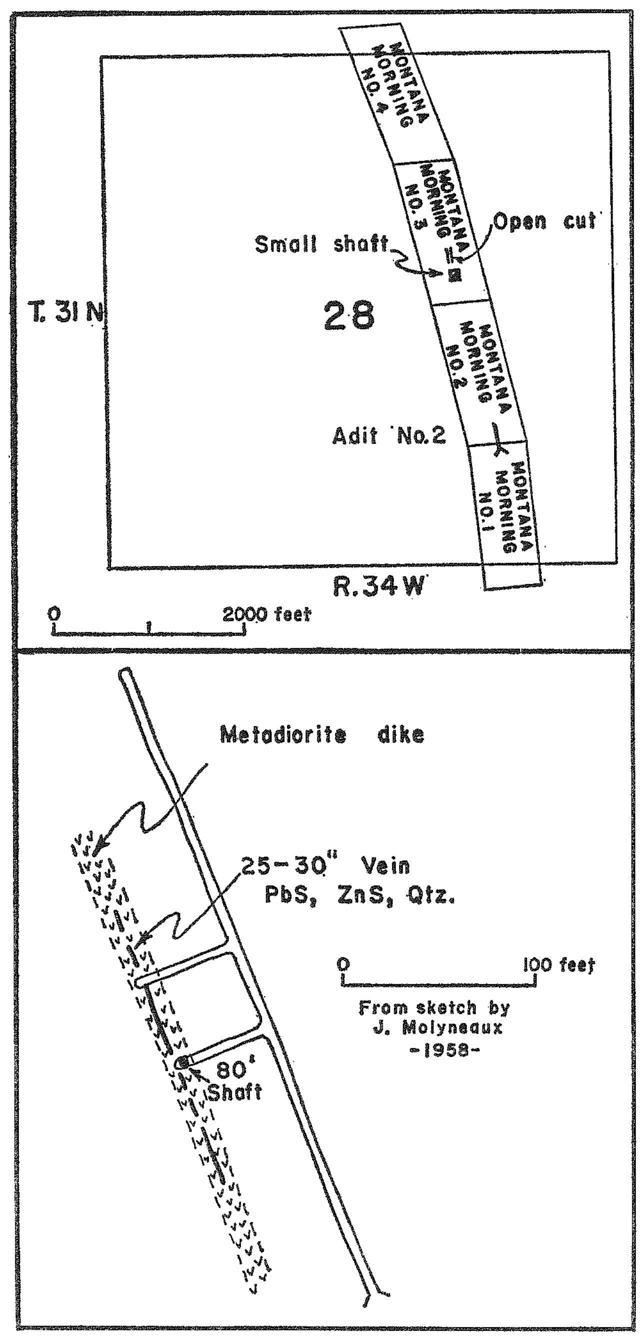


Figure 26.—Claim map of Montana Morning group and sketch of No. 2 adit, Troy district.

ed that the adit was caved 30 feet from the entrance. In later development work a 20-foot drift in the dike exposed stringers of galena and sphalerite in a quartz gangue.

No production has been reported from the property.

The nearby Universal, Silver Strike, and Cabinet Queen properties were reported to be active in 1958 and managed by Elizabeth Powers. Adits at these properties penetrate the Grouse Mountain dike and extend into, or start in Prichard argillite, which strikes about N. 25° W. and dips 50° to 55° SW. Lenticular and discontinuous quartz veins in or adjacent to shear zones in dike rock contain galena, sphalerite, chalcopyrite, arsenopyrite, and pyrite. Some calcite is present in the veins. Small quantities of anglesite and pyromorphite in shear zones at the Silver Strike resulted from oxidation of galena.

BIMETALLIC

The Bimetallic group comprises 13 claims on the southwest slope of Grouse Mountain. It is reported (1959) to be owned by Mr. McElroy of Troy and assessment work recorded by Jack Molyneaux. The property is believed to include the Black Horse described by Gibson (1948, p. 106).

Five adits, of which the longest is 800 feet and the others 100 to 200 feet in length, explore veins in the northwest-striking Grouse Mountain dike at altitudes to 3,800 feet. Several crosscuts explore the dike from these adits.

Quartz veins range in width from 5 to 11 inches and occur in fractured zones as much as 3 feet wide. The veins strike northwest and dip about 50° NE. In some locations the vein quartz exhibits ribbon structure. Masses of galena, which in some places constitute 80 percent of a 6-inch vein, are irregularly distributed and are accompanied by some arsenopyrite, pyrite, sphalerite, and chalcopyrite. Secondary anglesite, cerussite, some pyromorphite, and iron and manganese oxides have formed in oxidized specimens, and Gibson (1948, p. 106) reported covellite and chalcocite in specimens examined under the microscope.

According to Gibson (1948, p. 106), post-mineral faulting has sheeted the veins and in some localities has displaced them slightly. The veins are discontinuous, however, even where there is no faulting. In most sections of the veins the ore is oxidized to some extent.

The Grouse Mountain dike at the property has been altered to sericite, chlorite, carbonate minerals, and quartz. The workings and the dike are in Prichard argillite, which here strikes N. 25° to 30° W. and dips 55° to 65° SW.

DANIEL LEE

Three claims, Daniel Lee No. 1, 2, and 3, were originally located in 1958 and 52 additional claims were staked in 1963 to 1964 by Ernest Williams of Troy in the Mt. Vernon area southeast of Spar Lake near the head of the South Fork Stanley Creek and its tributaries. One pit had been excavated on the vein in 1959.

The quartz vein, about 10 to 15 feet thick, strikes N. 40° W. and is vertical, and it cuts the Ravalli Formation near the axis of a south-plunging syncline. A capping of Wallace strata overlies Ravalli quartzite and argillite on Mt. Vernon and along a ridge line to the west.

Quartz is the most abundant mineral, making up 95 to 98 percent of the vein. Pyrite, chalcopyrite, galena, and covellite are sparsely disseminated through parts of the vein. The upper several feet of surface outcrop contains iron and manganese oxides in vuggy parts of the vein. Malachite stains the outcrops, and molds of pyrite crystals are common. Sericite and chlorite in sulfide vein material probably were produced by hydrothermal alteration. Williams reported that about a quarter of a mile northeast of the property is a sheared zone, striking N. 80° W., which contains veins 2 inches to 2 feet wide across a width of 65 feet.

Disseminated copper minerals including chalcopyrite and bornite are reported to occur in Wallace strata in the Mt. Vernon area. The occurrence of these copper minerals may in part be related to fracturing adjacent to the synclinal axis and to an igneous stock reported to crop out on the north side of Ross Creek.

A grab sample of Ravalli quartzite obtained from outcrops along the South Fork Stanley Creek-Mt. Vernon road contained live limonite along bedding planes; the sample assayed 0.15 percent copper, 0.25 ounce silver, and 0.001 ounce gold a ton. This outcrop area, containing iron oxides believed to be in part derived from primary copper minerals, should be examined in greater detail.

SPAR LAKE COPPER

On the north side of Hiatt Creek six unpatented claims were located by L. W. Rubier, R. Rubier, B. Rubier, and E. Williams in 1958. The property lies on the southeast slope of Stanley Peak about a mile northwest of Spar Lake. A 1,200-foot road has been constructed to the property, and 4 cuts have been bulldozed across the vein. Ernest Williams subsequent to 1958 relinquished his interest in the claims, according to W. A. Rankin of Troy (personal communication).

A basic dike striking N. 45° W. intrudes Wallace quartzite and argillite, which in this area strikes N. 60° W. and dips 12° to 20° SW. Near the center of the dike is a 9-foot quartz vein, parallel to the dike trend, containing sparse pyrite, chalcopyrite, and bornite as disseminated masses and grains. Massive white quartz makes up 95 percent or more of the vein. Green copper staining is conspicuous for distances of 15 feet on each side of the quartz vein. Oxidized parts of the outcrop contain hematite in molds of pyrite crystals. Sulfide minerals are found within 10 feet of the surface.

BEAR

R. L. Bear and H. E. Bear of Kalispell reported a quartz vein containing considerable galena and sphalerite on a state section 1½ miles northeast of the Big Eight property. The vein is in a basic dike in the Prichard Formation and crops out on a steep hillside. Its position seems to coincide with the intersection of the dike and the trace of a synclinal axis. R. L. Bear reported that samples assayed as much as 20 percent lead and 3 ounces silver a ton.

WEST FISHER (CABINET) DISTRICT

MIDAS

The Midas mine includes the former Rose Consolidated and is on a tributary of Standard Creek, 2½ miles northwest of Teeters Peak. It lies half a mile west of the Waylett group and 2 miles north of the Montezuma prospect. Howard Lake is 1 mile northwest of the property. The mine has produced gold and tungsten, scheelite being first reported in the ore in 1916. Oscar Miller (personal communication) reported that U. S. Bureau of Mines engineers identified the mineral stolzite ($PbWO_4$, tungstate of lead) in the Midas vein. The property, now inactive, is developed by two shafts and 3,000 feet of drifts, crosscuts, and raises. One of the shafts is an incline sunk to a depth of 125 feet. The shafts and underground workings are inaccessible. A mill building, which contains a dismantled 75-ton flotation plant, and the ore bins and most of the other buildings have collapsed or been dismantled. The property was inactive in 1936, but it was under lease to the Stenstrom Brothers in 1941 (Reyner and Trauerman, 1949, p. 59). Gibson (1948, p. 86) stated that in 1932 the property included eight unpatented lode claims and one placer claim. In 1949 the property included the Ford placer, Northern Bell, and 15 other unpatented claims. Three claims have been reported patented in recent years. The claims were originally located in 1905 and later acquired by the Midas Gold Mining and Milling Company of Spokane.

Production from the property amounted to $59,000 from 1905 to 1933, and total production is believed not to exceed $60,000. Between 1916 and 1918 gold bullion and tungsten concentrates milled at the mine and valued at $27,000 were recovered from the ore produced. In 1919 the Rose Consolidated produced a small quantity of gold bullion. In 1928 the Rose property, operated by the Midas Gold Mining Company, ran 1,000 tons of test ore through the 75-ton mill, netting $6,034 (Gibson, 1934, p. 22), and in 1929 development work was reported in progress at the property. The Rose property produced a small tonnage of gold ore in 1931, and 4,500 tons of gold ore was treated by amalgamation in 1932 (Minerals Yearbook, p. 390). A cleanup of the Midas mill yielded some gold in 1933, and the mill treated some ore from the Midas mine during 1941. The mine shipped 10 tons in 1945. During the 1950's the property was leased to Oscar V. Miller. Mr. Miller has relocated the placer claim and several quartz claims in the vicinity. During the summers of 1958 and 1959 he sluiced mill tailings dumps for gold and scheelite, and reported recovering 16 ounces of gold and considerable scheelite.

Gibson (1948, p. 87) described the Midas vein as a bedding-plane vein ranging from a few inches to 6 feet in thickness, and averaging 1 foot. The vein strikes N. 20° to 30° W. and dips 40° to 60° NE. The sedimentary rocks are gray calcareous and sandy argillite and siltstone, quartzite, and laminated and contorted buff-weathering gray limestone of the Wallace Formation.

Quartz and some carbonate vein minerals contain scheelite and sparser galena, sphalerite, tetrahedrite, chalcopyrite, and malachite. Sericite and chlorite occur with native gold. The gold is deep yellow and most of it is gnarled and wirelike. Within the developed vein, ore minerals are incompletely oxidized.

Brecciated and silicified rock, consisting of limestone fragments in vein quartz, indicates (Gibson, 1948, p. 87) faulting before or contemporaneous with the introduction of vein quartz; the vein may have occupied a fault. Postmineral faulting occurred along north- or northeast-trending faults. Jack Larue (personal communication) believed that the vein was displaced at the main shaft and at a point 200 feet south of the main shaft by east-trending fractures and that the latter fault may displace the vein as much as 450 feet. In 1959 Mr. Miller was attempting to find the faulted(?) south extension of the vein.

FISHER CREEK

The Fisher Creek property was formerly known as the Branagan mine and was one of the early producers in the Libby area. The group of eight patented claims on Bramlet Creek (Fig. 27), a tributary of West Fisher Creek, is owned by the Fisher Creek Mining Company. In 1900 (Hunter and Byrne, 1900) the Fisher Creek Mining Company was actively developing the property. A tramway and 15-stamp mill had been constructed to convey and treat ore from the mine. In 1900 to 1901 development included five adits 250 to 450 feet long (Fig. 28), and the stamp mill was treating 30 tons of ore per shift in a 10-stamp mill. Production from the property during the period 1901-1903 was reported to be 18,000 tons of ore. In a run of 26 months the owners produced $150,000 although milling was only 60 percent efficient (Gibson, 1948, p. 83). The mine was inactive in 1905 to 1906 and in 1936. The Courageous Mining Company produced 24,239 tons of gold ore in 1940 to 1941 and 1950. Sandvig (1947, p. 53) estimated total production at $300,000 to 1947.

Discontinuous gently dipping bedding-plane quartz veins in east-dipping Prichard argillite have been developed by ten adits as much as 500 feet long, interconnected underground by extensive stoping. Stopes are irregular and range in height to as much as 12 feet. Lenslike parallel and cross-cutting quartz veins are 1 to 4 feet wide, and wall rock adjacent to the larger veins is impregnated with quartz veinlets and disseminated sulfides. Underground workings have explored some veins

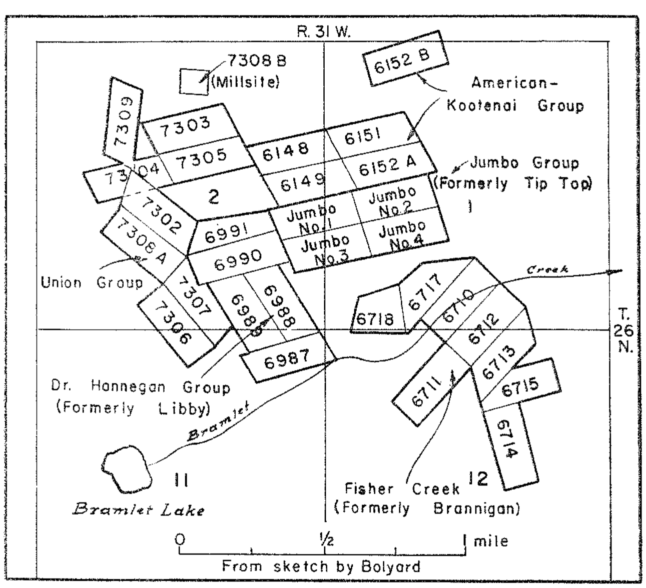


Figure 27.—Sketch of claims in Bramlet Lake area, West Fisher district, Lincoln County.

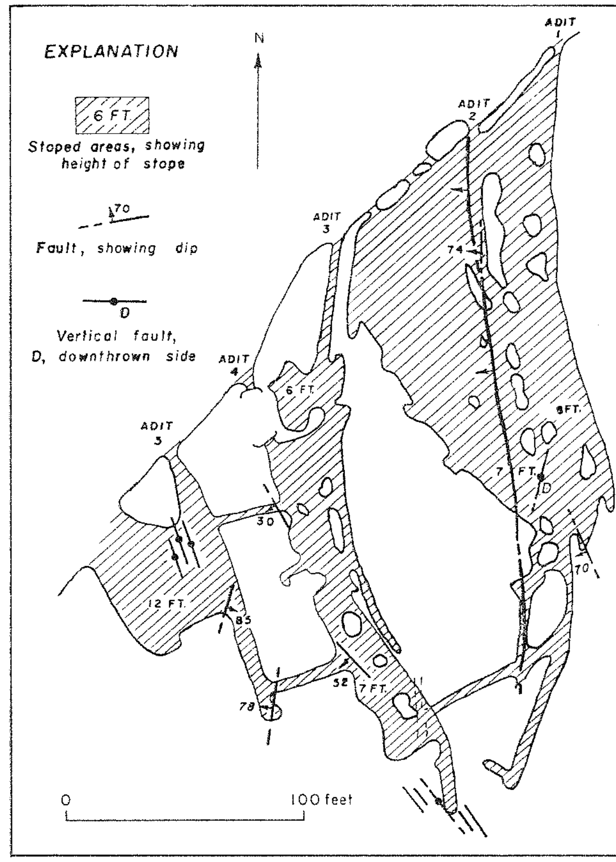


Figure 28.—Plan of Fisher Creek mine, West Fisher district. (After Gibson, 1948).

for a strike length of 500 feet. Prichard strata are nearly horizontal locally, but the general attitude of the bedding is N. 30° to 40° W. and dips range from 18° to 35° NE. Visible native gold has been reported by Gibson (1948, p. 83) from the face of Adit 4.

Gold-bearing oxidized quartz-sulfide veins containing sparse to moderate amounts of partly oxidized pyrite, galena, sphalerite, chalcopyrite, and pyrrhotite, are exposed in the stopes. Better ore was mined from those parts of the veins that were strongly oxidized. Pyrite and galena are the most common sulfide minerals in the veins, and the sulfides occur as disseminated grains and bunches in or adjacent to sheared zones. Gangue minerals are quartz and sericite. Partial oxidation of sulfide masses results in friable patches discolored by iron oxides and small amounts of manganese oxides. Gibson assayed an oxidized specimen of ore containing sphalerite, galena, and pyrite, and reported 1.66 ounces gold and 1.44 ounces silver a ton.

Steep west-dipping to vertical fault fissures containing 12 to 24 inches of gouge and breccia strike north and displace veins in the stopes.

Vertical displacement on faults exposed in the adits probably amounts to only a foot or two, and the downthrown side is on the east, but horizontal movement may be greater than vertical movement. The faults contain little or no ore, and latest movement on the fissures took place after deposition of the quartz.

The adit portals, which are on a steep northwest-facing slope, are now difficult to reach since high water in Bramlet Creek removed the mine dumps. Mining and milling equipment has been removed, and most buildings on the property have collapsed. In the early 1960's Arlin C. Lewis of Kalispell located a placer claim on mill tailings in Bramlet Creek some distance below the former mill site.

JUMBO

The Jumbo group, formerly part of the Blacktail, Tip Top, and New Deal properties, includes four unpatented claims on the north side of Bramlet Creek (Fig. 27). The property is owned by L. W. Bolyard of Libby, Montana. An aerial tramway and surface buildings, including a 10-stamp mill housing amalgamation and gravity concentration units and ore bin, were collapsed or in poor condition in 1959. Development work includes cuts, trenches, and adits, the longest adits not exceeding 300 feet. Larger veins have been selectively stoped. All development work is in the oxidized zone where enrichment of gold has taken place.

In 1901 the Blacktail mine, operated by the Blacktail Mining Company, was being developed by several short tunnels, and a 10-stamp mill had been erected but operated for a short period only. The Blacktail property was being operated by lessees in 1909 (Mineral Resources, 1909, p. 377), and in 1911 the property was again active, ore being milled in a 10-stamp mill. Gold ore was produced in 1928 to 1929 from Tip Top, and 100 tons of ore was treated in a stamp mill during 1930 and about half that amount in 1931. Gibson (1948, p. 88) gave a figure of $2,300 for ore produced in test runs prior to 1934. For 1934, 1937, and 1938, Minerals Yearbook listed the New Deal (Tip Top) as a producer of gold ore. The property was active as late as 1940. In 1941, 25 tons of gold ore from the New Deal was milled in the Tip Top mill.

Numerous quartz veins a fraction of an inch to 2 feet thick conform to sedimentary bedding or are at slight angles to bedding. A few crosscutting veins are nearly perpendicular to bedding. Veins are irregular, forming podlike masses that pinch and swell along strike. Most veins are flat or dip gently eastward. Country rock adjacent to the larger veins is impregnated with quartz veinlets a fraction of an inch wide, and wall rock is in many places impregnated with native gold. In some ores gold is easily seen or can be detected with a hand lens, but even where no gold is visible, the rock assays small amounts of precious metals.

Particles of native gold are irregular, gnarled, and rough; most are thin and range from microscopic particles to wheat-sized fragments. Sulfides are scarce within the veins, and where they are found they are partly altered or represented only by their alteration products. Pyrite, pyrrhotite, and sphalerite occur in a gangue of quartz, iron oxides, and sericite. The quartz contains voids and pits formerly occupied by sulfides but now containing alteration minerals, most of which are iron oxides. Weathering of sulfides gives the quartz a honeycombed and rough appearance, and some quartz veins show ribbon texture.

The prospect is in white, light- to medium-gray, and blue-gray sericitic argillite and sandstone of the Prichard Formation, which strikes north to N. 20° W. and dips east. Near the quartz veins the sandstone and argillite contain disseminated grains of iron sulfide minerals or cavities once occupied by these sulfide minerals but now filled with iron oxides.

An important structural feature in this and nearby areas is an anticline whose axis strikes slightly west of north. Quartz veins occur on both flanks of the fold, although most of the productive properties are on the east flank. A favorable vein zone is in sericitized light-gray argillite or white sandstone. In one such bed, quartz veinlets over a thickness of several feet assayed $1 to $7 a ton in gold. Gold-bearing quartz veins as much as 2 feet thick assay $15 to $60 a ton. Average gold content of ore lenses in these veins is about $28. One selected specimen was reported to assay 4.90 ounces gold and 1.39 ounces silver a ton.

AMERICAN KOOTENAI

North of and contiguous with the Jumbo group (Fig. 27) is the American Kootenai group on the south side of West Fisher Creek. The property consists of five patented claims, the Gold Den (MS 6148), Jim Blaine (MS 6149), Gold King (MS 6151), Gold Bug (MS 6152A), and Gold Bug millsite (MS 6152B). The group, owned by L. W. Bolyard of Libby, was inactive in 1959. These claims are developed by three adits totaling 600 feet in length. The mine was operated by the American Kootenai Mining & Milling Company during the period 1899 to 1910, when the principal mineral mined was gold. A 2,240-foot aerial tram conveyed the gold-bearing lead-silver ore to a 10-stamp mill constructed prior to 1901. During the summer of 1906 the property was closed because of a disagreement among the stockholders (Walsh and Orem, 1906), Gibson (1948, p. 90) reported that the surface plant was destroyed by fire in 1910. Walsh and Orem (1910) stated that part of the mill was destroyed by a snowslide in 1910.

Bedding-plane veins are a few inches to as much as 5 feet thick but the average thickness mined was about 2 or 3 feet. Crosscutting veins 15 to 20 inches wide in white sandstone occur near thicker bedding veins. This sandstone fractures in such a manner as to make an open clean break, easily accessible to mineral-bearing solutions and is therefore a favorable zone for ore. Quartz veins contain some pyrite, but other metallic minerals are rare. Oxidation has been thorough in areas penetrated by present workings. Veins are irregular in trend; they pinch and swell within short distances. Quartz, pyrite, iron oxides, and some gold are the vein minerals in the oxidized zone. Post-vein faults striking northwest have fractured the veins but caused little or no displacement. The veins are in the Prichard Formation, which strikes N. 3° E. to N. 20° W. and dips 5° to 40° E. Average dip of beds is about 30° E.

UNION

The Union group or Union lode comprises eight patented claims and one millsite between Bramlet Creek and Mill Creek, tributaries of West Fisher Creek. The group is composed of the Ismore (MS 7302), Evening (MS 7303), Last Chance (MS 7304), Treasure Vault (MS 7305), Ekalaka (MS 7306), Minnie W. (MS 7307), Union Lode (MS 7308A), Union Millsite (MS 7308B), and Brookland Placer (MS 7309). L. W. Bolyard of Libby owns the claims, which were inactive in 1959.

Quartz veins occur on the east flank of an anticline, where the Prichard Formation is horizontal or strikes N. 10° W. and dips 5° NE.

HANNEGAN

Five patented claims, formerly known as the Libby, are owned by Dr. Hannegan of Libby, Montana. They are contiguous with the Jumbo group (Fig. 27). The property has been inactive for some time. Development is by several adits 100 to 350 feet long driven in a southerly direction to explore veins in the Prichard Formation.

Country rock is sericitic quartzose sandstone and sericitic argillite displaying abundant red-brown iron oxides on rock surfaces and as tiny blebs scattered throughout the rock matrix. Fracture cleavage in the argillite is so prominent that in places the bedding has been obscured.

Numerous irregular quartz veins about 2 feet thick occur as bedding veins and as crosscutting veins following cleavage. Both kinds of veins pinch and swell within short distances and split into smaller veinlets. Metallic minerals present in the quartz veins are galena, anglesite, cerussite, pyromorphite, native gold, and iron oxides. Selected specimens are reported to have assayed about 0.50 ounce gold a ton.

The claims are on the east flank of an anticline whose axis in this vicinity trends N. 10° W. paralleling the strike of Prichard strata. Bedding is horizontal or dips gently eastward. The folding shattered Prichard strata, providing channelways for quartz-bearing solutions.

IRISH BOY

The Irish Boy prospect is on the south side of Lake Creek several hundred feet above creek level, and is reached by a hazardous road that follows Lake Creek, then ascends the slope to the workings. The property is developed by an adit and several cuts. In 1959 it had already been inactive for some time.

Bedding veins as much as 6 inches thick and crosscutting veins as much as 12 inches wide and parallel to fracture cleavage are exposed in cuts and in the adit. Prichard country rock is brown sandstone and argillite striking N. 20° W. and dipping 15° to 30° E.

Galena, anglesite, sericite, and iron oxides are sparse in quartz and carbonate gangue. A sample of galena-rich material analyzed by Gibson (1948, p. 95) assayed a trace of gold and 5 ounces silver a ton.

GLORIA

The Gloria (Little Annie) was one of two properties formerly controlled by the Golden West Mining Company. The Gloria is near the headwaters of West Fisher Creek and on the north side. The Golden West (formerly New Mine) is on the south side of the West Fisher. A road passable by 4-wheel-drive vehicles follows West Fisher Creek almost to its head, then ascends the north slope to the property. A well-built cabin is at the head of West Fisher Creek on ground formerly owned by the Golden West Mining Company.

In 1959 one claim was relocated as the Gloria by A. Templin and R. Seifkie of Libby and A. C. Lewis of Kalispell. Mr. Lewis also relocated several other claims in the vicinity and after several years acquired ownership of the Gloria property. Development work amounts to 300 feet of advance, including two northeast-trending adits connected by a crosscut.

Gibson (1934, p. 20) reported that a shipment of 39 tons of ore yielded 3.874 ounces gold and 1.05 ounces silver a ton. Small shipments of ore mined in the early 1930's assayed between 8 and 9 ounces a ton in gold. Gold ore was shipped from the Golden West group in 1939 (Minerals Yearbook 1940). A sample taken recently by Arlin Lewis across a 16-inch width assayed 4.88 ounces gold, several ounces silver, and some lead and copper.

At the Gloria, quartz veins as much as 2 feet thick lie nearly parallel with bedding. Bedding here is horizontal or dips at slight angles northwest; the veins are a short distance west of the axis of a major anticline. Visible native gold, galena, sphalerite, chalcopyrite, pyrrhotite, pyrite, siderite, and sericite are present in the quartz veins.

Native gold in milky-white quartz or associated with sulfides is pale to bright-yellow very small particles, nearly invisible to the naked eye, or irregular visible particles, some smooth, others gnarled or wirelike. In some specimens, native gold is associated with very fine grained pyrite and a gray mineral believed to be tetrahedrite.

Gibson (1948, p. 86) reported that ore being mined at the time of his visit (1931) was little oxidized. At other properties in the quadrangle, however, ore mined principally for gold content was not regarded as workable below the zone of oxidation.

Faulting parallel to the veins and bedding is indicated by slickensides on quartz surfaces and by shattered and broken areas within the quartz veins; gold and sulfides are more likely to be found in these places. Nearly vertical cross faults displace the veins and show small net displacement. Country rock at the Gloria is laminated blue-gray Prichard argillite, striking slightly west of north and dipping gently to the west.

WAYUP

The Wayup property, opened in 1902, is near the base of Twin Peaks at an altitude of 5,600 to 5,800 feet and about 1 mile southwest of the Gloria. Two patented claims, the Montana (MS 6305) and Wayup (MS 6306), and ten unpatented claims are on the north side of West Fisher Creek. They are reached by the West Fisher Creek road via a turnoff from the road to the Gloria property. The last mile of the Wayup road was still inaccessible in late June 1959 because of snow. The property was reopened in 1937 and was active in 1948 to 1949, when V. A. Harpole of Libby and Deer Lodge, Montana, was listed as the owner. In 1959, John Malloy of Libby and two associates from Avon, Idaho, were leasing the property, which had been active for several years.

A 4-foot shear zone is developed by three accessible adits one above another (Fig. 29) for distances totaling about 1,100 feet, and by a pit. Quartz veins about 2 inches wide are irregularly distributed throughout the sheared zone. Other quartz veins as much as 8 inches wide have been developed by short crosscuts from the tunnels. The

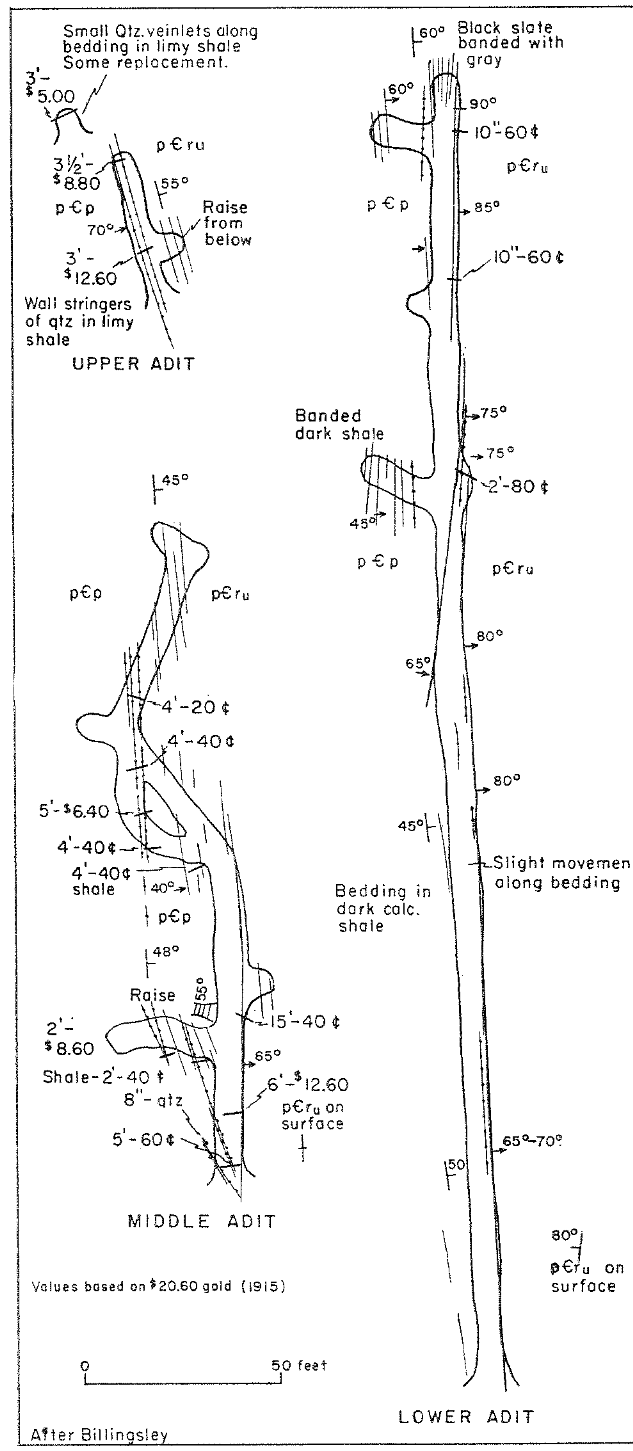


Figure 29.—Geologic plan of lower, middle, and upper adits, Wayup mine, West Fisher district.

zone strikes north to N. 25° W., and dips range from 65° E. to vertical.

Quartz veins in the sheared zone and along cleavage and bedding planes in the country rock contain sparse galena, pyrite, and native gold. The shear zone is the fault contact between calcareous white quartzite of the Ravalli to the east and dark- and medium-gray laminated argillite and shale of the Prichard to the west. Some of the shale and argillite is calcareous, indicating that these strata may represent upper beds of the Prichard. Prichard strata dip steeply southwest; Ravalli quartzite strikes north to N. 20° W., and dips range from vertical to 45° E. Drag folding is obvious on both sides of the shear zone. Prominent fracture cleavage in places nearly obliterates bedding.

Selected samples of dump material assayed 0.50 ounce gold and 0.50 ounce silver a ton.

WILLIAMS

The Williams prospect, consisting of eight unpatented claims, is at the head of a tributary of Libby Creek west of Great Northern Mountain. A steep road, via Standard Creek, which can be traveled only by 4-wheel-drive equipment, terminates at the top of Great Northern Mountain. The property is reached by trail from this point. The claims, some of which are on the ridge between Great Northern Mountain and Twin Peaks, are developed by trenches and four adits at altitudes between 5,900 and 6,400 feet. The adits are partly caved at their portals and there has been no activity at the property for many years.

One adit (still accessible), about 300 feet long, has been driven on a 2-foot vein of galena-bearing quartz that follows bedding. Oxidation products derived from the lead sulfide are anglesite and cerussite; iron oxide pseudomorphs formed from pyrite. Sericite is present in the vein. Crosscutting galena-rich quartz veins as much as 2 feet thick strike northeast to east and contain anglesite, cerussite, sparse chalcopyrite, and hematite. The cross structures dip south or southwest and are irregular in width, showing a tendency to pinch and swell along strike.

Country rock is gray argillite of the Prichard Formation, which is horizontal or dips gently east.

Gibson (1948, p. 93) observed that movement has taken place along the walls and within the veins, especially between vein quartz and slivers and masses of sericitic shale, which have been partly replaced. He observed that the sericite seems to have acted as a lubricant.

A galena-rich specimen containing sparse chalcopyrite was reported to assay 0.04 ounce gold and 8.71 ounces silver a ton.

MUSTANG

The Mustang prospect is 2 miles southwest of the Midas mine on the south side of Standard Creek. A road passable by 4-wheel-drive vehicles parallels Standard Creek and a small tributary as far as the property. The group of four unpatented lode claims has been inactive for some time. No production has been reported from the property, and the present status of ownership is unknown.

Development includes a 700-foot adit and an open cut. The adit explores an 18-inch quartz vein, which splits into a zone of closely spaced quartz veinlets a few inches thick. The quartz vein almost parallels the bedding but in places it dips more steeply than the bedding. A surface exposure, believed to be the lode outcrop, is 2½ feet wide. Some sections of the vein show a ribbon quartz structure, which may indicate that quartz partly replaced the sheared and shattered wall rock. Metallic minerals are galena, pyrite, and pyrrhotite in a gangue of quartz and iron oxides. Gibson (1934, p. 23) assayed a specimen of brecciated iron-stained vein quartz, which yielded 1.49 ounces gold and 2.11 ounces silver a ton. Premineral faulting and shearing was followed by contemporaneous deposition of quartz and sulfide in permeable sections of the broken and shattered fault zone. Brecciated and broken quartz signifies postmineral fracturing. Most of the workings are in the oxidized zone, where iron oxide staining is conspicuous.

Country rock is gray and light-gray-white shaly calcareous argillite and sandstone of the Ravalli Formation. Pyrrhotite is abundantly distributed throughout some sandstone layers. Bedding strikes N. 20° to 30° W. and dips 30° NE.

BETTY MAE

The Betty Mae property comprises six unpatented claims on Goat Creek, a northwest-flowing tributary of Libby Creek. This prospect has been developed by several shallow cuts and pits but is now inactive.

Thin irregular veins and veinlets of galena-bearing quartz conform to horizontal or gently northwest-dipping beds of gray argillite and sandstone of the Prichard Formation. The veins also contain some chalcopyrite, sphalerite, and pyrrhotite. Oxidation products of galena are anglesite and cerussite. Some melanterite and native copper has also been reported. Postquartz movement prior to deposition of sulfides is indicated by shearing and shattering of quartz. Additional postsulfide movement has shattered the sulfides to a small extent. Gibson (1948, p. 93) reported that a selected sample contained 10 percent copper, 20 ounces silver, and 0.50 ounce gold a ton.

DIAMOND JOHN

On the north side of Libby Creek near its headwaters is the Diamond John prospect, which is developed by a 60-foot adit trending northwestward. The adit is on the east flank of an anticline where brown-weathered gray and blue-gray siliceous argillite of the Prichard Formation strikes about N. 20° W. The general attitude of bedding is east but locally the dip is to the west.

Two west-dipping quartz veins separated by about 3 feet of country rock strike N. 20° to 25° W.; they attain a maximum width of 16 inches along strike. Minor amounts of galena, sphalerite, chalcopyrite, and pyrite and a moderate amount of pyrrhotite are contained in milky-white quartz. Sulfide minerals are most abundant in shattered and broken sections of the vein where fracturing parallels bedding.

Assays indicate that the vein carries small amounts of gold and silver in addition to lead, zinc, and copper.

MOTHER LODE

Near the head of West Fisher Creek is the Mother Lode property. The claims are on the southwest slope of Great Northern Mountain at an altitude of about 5,500 feet. Development is by an adit 160 feet long mapped by Paul Billingsly in 1915 (Fig. 30). No production has been reported from this property.

A gold-bearing quartz vein striking N. 30° to 40° W. is a few inches to 2 feet wide. The vein is on the east limb of an anticline, a major structural feature in the West Fisher district. The north end of the vein terminates against a large fault, which strikes N. 30° W. and dips 80° E. Near the face of the adit a vertical split diverges on a bearing of N. 25° W. Small fractures trending N. 20° W. and dipping 60° E. parallel the adit; others striking N. 80° to 85° W. and dipping 20° N. cross the adit. The vein is in Prichard argillite, which strikes N. 15° to 20° W. and dips 28° to 45° E. The Prichard-Ravalli contact is approximately 1,100 feet northwest of the portal.

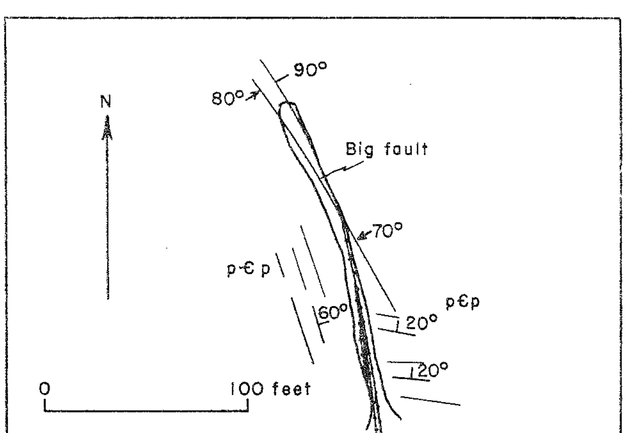


Figure 30.—Geologic sketch of Mother Lode adit, West Fisher district.

YAAK RIVER AREA

NEW MORNING GLORY

The Morning Glory mine west of the Yaak River near Sylvanite comprises consolidated properties formerly known as the Morning Glory, Keystone, and Goldflint, which Calkins and MacDonald (1909, p. 102) reported were on the same vein. Hunter and Bryne (1897) reported that in 1897 the Keystone Mining Company employed 18 miners and the Goldflint Mining Company hired one surface man. In 1898, twelve men were employed at the Keystone and 33 men were working on the Goldflint mine. Walsh and Orem (1910) reported that the most active mining camp in Lincoln County was at Sylvanite, where the Lincoln Mining Company, operating the Keystone group, employed 35 men. During 1912 the Keystone group was inactive. The property was being developed by Clyde Thornton in 1958 and by a Coeur d'Alene mining company in 1959. In the early 1960's it was inactive.

In 1898, the Keystone was developed by a 200-foot tunnel and raise to the surface, and a crosscut tunnel 500 feet long with drift extensions (Hunter and Bryne, 1897, 1898). Reported tunnel development for the Keystone group by 1910 amounted to adits 700 and 900 feet in length. Development at the Goldflint (1897) amounted to a 360-foot adit and a raise to the surface. The Victoria mine (near the Keystone), whose copper-gold-silver sulfide ore body was developed by an 800-foot tunnel, was active in 1910 (Walsh and Orem, 1910).

In 1897 a 10-stamp gold-silver mill was operating at the Keystone property. The next year a 20-stamp mill was erected at the Goldflint. In 1910 the Keystone group constructed a 200-ton mill and a 2,400-foot aerial tramway.

Present underground and surface installations consist of two accessible adits, one incline shaft and adit (inaccessible), an abandoned stamp mill, and several collapsed buildings.

From 1931 to 1937, production from the Sylvanite mines amounted to slightly more than 22,200 tons of ore valued at $246,000. It was reported that the Thornton brothers operated the property during this period, and produced ore from a 20-foot quartz vein. Total production from 1901 to 1937 was 22,400 tons of ore valued at $248,000. High-grade ore was mined in 1897 and 1898, but production figures for this period are not available.

The country rock is Prichard quartzite and argillite that strikes N. 20° W. and dips 30° NE. The beds range from white and gray quartzite to dark- to light-gray thin- to medium-bedded shaly argillite. Metadiorite dikes are present in the area.

MacDonald (1909, p. 103) reported production at the Keystone and Goldflint from a 1- to 2-foot quartz vein, dipping 30° E. and paralleling the bedding. At the time of his visit the operators were mining auriferous pyrite and native gold. Two nearly vertical veins, striking N. 40° W., crop out about 1,400 feet southwest of the upper Morning Glory adit. These veins are 10 and 40 feet wide, and are composed of massive white quartz. Another vuggy vein, 2 to 4 feet wide, strikes north and dips 40° E. This may be the vein described by MacDonald. It lies 1,000 feet west of the upper New Morning Glory adit and contains abundant iron oxides and quartz. An incline shaft (inaccessible) estimated to be several hundred feet deep is on this vein.

Vein material filled longitudinal faults and smaller fractures along the axis of the northwest-striking Sylvanite anticline. The 2-foot vein was productive at an early date, but low-grade ore was later mined from a 20-foot vein. Gold from the Snipetown placer may have been derived from the Sylvanite veins. A selected specimen from an upper Morning Glory adit assayed 0.64 ounce gold and 3.20 ounces silver a ton.

DUPLEX

The Duplex property is 1½ miles south-southeast of Leonia on a small north-flowing tributary of the Kootenai River. The five unpatented claims were owned by A. M. Bartlett and L. Lemire of Troy in 1958.

Recent production from pillars amounted to 100 tons of ore, which was shipped to East Helena. Net value from smelter returns was $36 a ton, and Mr. Bartlett stated that one heading produced ore assaying $112 a ton. Stoping in an upper adit was done prior to acquisition by Mr. Bartlett.

Development consists of two adits, each 200 feet long, and a 20-foot winze. The adits are accessible but hazardous. The winze encountered water that hampered sinking operations.

The vein is in a metadiorite sill between sedimentary beds of the Prichard Formation. More detailed field work may be necessary to determine the relationship of the igneous body and country rock. Similar structures on the Idaho side of the boundary have been mapped as sills.

The vein, trending diagonally across the sill, is as much as 3½ feet wide. Near the portal of the adit the vein strikes N. 70° E. and dips 70° SE. At the portal the vein is displaced by a fault, which strikes N. 15° E. and dips 40° SE. Within the fault a 1-foot shattered zone contains fragments of brecciated country rock and gouge. The vein has been offset about 10 feet.

Ore minerals are galena, sphalerite, chalcopyrite, and pyrite, containing traces of gold and silver. Gangue minerals are quartz and calcite.

ORO

The Oro property, on the north side of Ruby Creek near its headwaters, was discovered during logging operations in 1935, and was subsequently staked by Ronald and Norman Obermayer. In 1947 the property was leased by the Bunker Hill Company of Kellogg, Idaho. Later the property was acquired by Inspiration Lead, who did considerable development work. The ground has been recently relocated by W. G. Dailey and L. R. Rittenhouse.

The vein is developed by a 600-foot adit and an upper adit, the latter now inaccessible. A bulldozer cut, 100 feet in length, exposes a quartz vein in a metadiorite dike about 75 feet below the upper adit. The dike strikes N. 40° W. and contains a quartz vein several feet wide. The dike may be an extension of the Snowstorm dike from Callahan Creek.

The ore consists of galena, anglesite, chalcopyrite, and pyrite in quartz. A stockpile of vuggy material containing abundant iron oxides and quartz assayed 5.10 percent lead, 0.40 ounce silver, a trace of gold, copper, and zinc, and 3.30 percent iron. Some ore was reported shipped to the Bunker Hill smelter.

Tom Schessler, mineral evaluator for the U. S. Forest Service, reported that a sample of disseminated lead-copper ore from a sill in the locality assayed 0.50 percent nickel.

BLACK DIAMOND

The Black Diamond property, consisting of three unpatented claims about 1½ miles west of Tepee Mountain, was relocated by W. A. Rankin of Troy in 1958, having been idle since 1941. The property was discovered in the early twenties and the mine was developed and financed by Charles Cone and other interested Troy and Libby residents operating as the Black Diamond Mining Syndicate.

This property has been developed by four adits, one of which is 500 feet in length. The lower adits are accessible. Considerable ore has been mined from a glory hole in a sheeted zone. In 1936 two men were employed in development work.

A 100-ton gravity-flotation mill, erected in 1936, produced a lead-zinc concentrate containing 30 percent lead. The operators planned then to increase capacity to 150 tons by the addition of rolls and to make separate lead and zinc concentrates. Other buildings and equipment included a sawmill, bunkhouse, and powerhouse containing a diesel motor and electric generator. It is reported that $30,000 was spent on the camp. Prior to 1958 the mill was partly torn down and the machinery removed, and all other buildings have been removed.

Native gold is associated with quartz and some galena, pyrite, sphalerite, chalcopyrite, and pyrrhotite. Quartz veins and veinlets occur in Ravalli quartzite. Veins are a few inches to about 2 feet wide, whereas the veinlets in the sheeted zone are ¼ to ½ inch wide. The quartz veins and veinlets strike north to northeast and dip east to southeast. Larger veins are steep to vertical. The ore body is reported to be 400 by 600 feet but too low grade to be mined by nonselective methods. W. A. Rankin reported that selected specimens assayed 3 ounces gold a ton. The sheeted zone and adjacent quartz veins are a short distance east of the O'Brien Creek fault where a metadiorite dike lies adjacent to or within the fault.

STATE LINE

The State Line prospect lies approximately 1,000 feet southwest of the Leonia railroad siding. It was located in 1956 by H. L. Kiser and R. Kimberlin. The property consists of one unpatented claim, the Leonia Paymaster No. 1. A cut penetrates the hillside for a distance of 10 to 12 feet adjacent to the Leonia-Star Creek road.

An 8-foot metadiorite dike, which strikes N. 50° W. and dips 65° NE, encloses two quartz veins. One vein, 3 to 5 inches wide, parallels the strike of the dike; the other, a vertical vein 3 inches wide, crosscuts the dike. The dike is enclosed by dark- to medium-gray argillaceous quartzite of the Prichard Formation. Wall rock alteration is weak at the dike contact, although quartzite has been weakly recrystallized, and some silicification was noted. Sericitization is weak to absent. The dense white to gray quartz veins contain pyrite, limonite, hematite, and possibly some gold, but no gold was visible in hand specimens. Quartz monzonite float found in the vicinity may be glacially transported.

YAAK FALLS

The Yaak Falls prospect is approximately 100 feet west of the road at Yaak Falls. The vein is in dark- and medium-gray quartzite and siliceous argillite of the Prichard Formation. Development is by a 150-foot accessible adit following the vein. Crossing the Yaak River at Yaak Falls are several veinlets of quartz and galena a fraction of an inch to 1 inch wide.

In the adit a 10-inch quartz vein strikes east and dips 60° S. Minerals include milky white and light-gray massive quartz and iron and manganese oxides. A channel sample near the portal assayed traces of gold, lead, and zinc, and 0.04 percent copper and 0.30 ounce silver a ton.

RANKIN

The Rankin prospect is 1½ miles south of Yaak Mountain, and is developed by a 6-foot pit in gray dolomitic limestone and calcareous argillite of the Wallace Formation. Wallace beds strike N. 10° W. and dip 80° NE.

Several quartz veinlets, ¼ inch to 3 inches wide, parallel bedding. A metadiorite dike was mapped a short distance west of the pit, and a stocklike mass of metadiorite crops out southwest of the prospect.

An assay of dump material showed a trace of gold and 0.10 ounce silver a ton.

McEWEN

The McEwen prospect is 7 miles above Libby in the Pipe Creek drainage. Mineralized matter consists of pyrite, chalcopyrite, and iron oxides in quartz. Selected specimens assayed 1.06 percent copper and 0.10 ounce silver a ton.

FERREL

The Ferrel prospect is about ½ mile southwest of Yaak Falls. An adit now inaccessible lies about a quarter of a mile west of the Yaak road. Dump material indicates that the workings were driven on a dark-gray argillite (Prichard) containing seams of pyrite probably formed nearly contemporaneously with deposition of the argillite. Selected dump specimens assayed traces of gold, silver, and the base metals.

CANUCK COPPER

The Canuck Copper claim was staked by Robert Sands, W. E. Fields, Diane and Claude Burrus, and L. M. and F. Piatt in July 1960. The prospect is on American Creek, adjacent to a logging access road into the area, and about midway between American Mountain and Northwest Peak.

Along the road a 6- to 8-inch vertical quartz vein containing chalcopyrite, galena, pyrite, and pyrrhotite strikes east-west in a metadiorite sill(?). The igneous body is covered except for a small exposure adjacent to the vein. The exact relationship of igneous rocks to sedimentary rocks is unknown. Prichard strata in the area strike north and dip 36° E.

A sample across a width of 6 inches assayed 0.20 percent copper, 0.73 percent lead, 0.015 ounce gold, and 0.20 ounce silver a ton.

PHILLIPS

The Phillips prospect is at the foot of a small falls on the East Fork Yaak River about 2 miles northeast of Zimmerman Hill. Elmer G. Phillips of Yaak owns (1958) the mineral rights to this quarter section.

Development consists of a small caved pit on a vein on the north side of the river. The pit was excavated for a distance of about 8 feet into the hillside. The quartz vein is about 18 inches wide and strikes N. 20° W. and dips 58° NE. It contains pyrite, malachite, and a trace of iron oxides. The vein is believed to occupy a fault zone that crosses the Yaak River at the prospect. The west side of the fault has dropped about 30 feet, causing the falls on the East Fork Yaak River.

A sample representing the full width of 1½ feet assayed 0.02 ounce gold and 0.20 ounce silver a ton.

HOERNER

The property staked by Vincent Hoerner of Columbia Falls consists of one claim on the west side of Spread Creek north of the Yaak road.

A vertical quartz vein in Prichard argillite near a metadiorite sill is 8 to 28 inches thick. The vein strikes east-west and the argillite strikes N. 5° W. and dips 16° E. A sample from the vein assayed traces of gold, silver, and copper.

OTHER PROSPECTS AND VEINS

A small caved pit was noted on a divide on Buckhorn Mountain, about 2 miles north of Keno Mountain. The pit may have been excavated in an attempt to find the southeast extension of the vein worked in the Buckhorn mine in eastern Boundary County, Idaho. Calkins and MacDonald (1909, p. 107) reported that the Buckhorn mine produced some "good looking" ore containing both gold and galena. Quartz around the pit showed slickensides but no metal.

About 1 mile north of Indian Peak on the North Fork Seventeenmile Creek is the Woods prospect, consisting of several unpatented claims owned in 1943 by E. A. Woods of Helena and L. Y. Lyons of Yaak. A 3-foot vein contains galena and sphalerite but there has been no production from the property.

Traces of metallic minerals were observed in float found in the upper part of Hudson Creek valley on the northwest side of Mount Henry. A grab sample assayed 0.03 percent copper, 0.18 percent lead, 1.96 percent ferric oxide, and 0.05 ounce silver a ton.

East of the divide and 2½ miles south of Keno Mountain is a 2½- to 4-foot quartz vein containing small amounts of chalcopyrite, malachite, azurite, tenorite, tourmaline, and epidote. The vein, developed by a 25-foot adit, is in a metadiorite sill. A selected sample from the vein assayed 0.95 percent copper, 0.02 ounce gold, and 0.50 ounce silver a ton. A 14-inch quartz vein on Red Top Mountain assayed 0.16 percent copper and 0.05 ounce silver a ton. A 28-inch vein west of Red Top campground assayed 0.035 ounce gold and 0.70 ounce silver a ton.

Other white or iron-stained quartz veins, ranging in width from several inches to 4 feet, contain sparse malachite, iron oxides, chlorite, tourmaline, epidote, and ankerite. Such veins were mapped east of the Kootenai River opposite the mouth of Ruby Creek, near the mouth of Hellroaring Creek, near the head of Forest Creek, ½ mile south of Keno Mountain, 1 mile east of Mt. Baldy, on the east slope of Keno Mountain, and 1 mile east of Mushroom Mountain.

THOMPSON LAKES AREA

MONTEZUMA

The Montezuma prospect is 2 miles southeast of the Midas mine on the east side of West Fisher Creek. The property was operated intermittently in the 1930's by Olson and Bolyard, and at one time it was owned by the late Jack Bohemia of Libby. It was later acquired by Jack Larue of Libby, and in 1959 was being developed by G. Derikson of Polson and A. C. Lewis of Dayton, Montana. Six unpatented claims (Hallelujah and Hallelujah 1 to 5) are in a group trending north. No production has been reported.

The property is developed by two adits (lower adit inaccessible), a 30-foot inclined shaft (inaccessible), and twelve or more pits and trenches. The lower adit, reported to be 385 feet long, was being reopened in 1959. The upper adit, 90 feet long, was accessible but difficult to enter.

The Montezuma veins are in basal Wallace beds of medium-gray to medium-light-gray argillite, shaly argillite, and argillaceous quartzite. A few thin- to medium-bedded zones of gray dolomitic limestone and light-gray to white quartzite are present northwest and northeast of the property. The Montezuma vein parallels the dip and strike of adjacent sedimentary beds, but in some places the dip is greater. The vein strikes N. 25° to 30° W. and dips 50° to 55° NE. The quartz vein in the lower adit is reported to be as much as 20 inches wide but average width is 10 inches. A 3- to 6-inch hanging-wall section of the vein assayed $50 a ton in gold (1.42 oz.). The vein in the upper adit averages about 14 inches in width. The vein material includes tetrahedrite, galena, sphalerite, chalcopyrite, pyrite, and minor amounts of azurite and malachite in a gangue of quartz and carbonate minerals. A dump sample from the lower adit assayed 0.68 percent copper, 1.0 percent lead, 1.5 percent iron, 0.12 ounce gold, and 8.30 ounces silver a ton. No scheelite was contained in the sample, but small amounts of tungsten are reported in the ore. Mr. Lewis reported that a representative sample from the upper adit assayed 76 percent silica, some lead and copper, and 1.30 ounces gold and 22 ounces silver a ton. After smelter and freight charges were deducted, the ore was valued at $55 a ton. A selected sample, across a 4-inch width, assayed $76 (2.17 oz.) a ton in gold and some silver. A 6- to 8-inch vein is exposed at the collar of the inclined shaft. A 3-foot banded vein of quartz and argillite exposed in an upper pit assayed $6.40 a ton in gold and silver. Other pits and trenches exposed quartz veins as much as 24 inches wide. The relationships of these veins are not clear; there may be two or more parallel veins in the areas.

WAYLETT GROUP

The Waylett or Moose Hill group of unpatented tungsten claims includes twelve lode claims, a placer claim, and a millsite. They are located between Teeters Peak and a west tributary of Miller Creek, 31 miles by road from Libby and 1 mile east of the Midas mine.

The area was first prospected in 1905 by McDonald and McKay, who were looking for extensions of the Midas vein. A quartz vein and a closely paralleling sheeted zone of quartz veinlets were discovered and later explored by an adit and several shallow shafts and pits. The very sparse gold content of the vein discouraged further work.

Scheelite was discovered in the Midas vein in 1916, and between 1949 and 1951, H. K. Waylett and R. C. Jones of Libby prospected the vein and sheeted zone, finding scheelite in several of the old pits and shafts. The Moose Hill claims were located in 1951. In 1952 the property was leased and optioned by J. C. Forkner of Fresno, California. Bulldozer trenching in 1952 and 1953 exposed the scheelite-bearing vein and sheeted zone.

Upon expiration of the first lease, Clair Wyncoop and Kenneth Morlan leased the property. Additional diamond drilling and trenching to determine the grade and extent of scheelite associated with the quartz deposits is reported to have cost $45,000. The lease expired in 1957, and subsequent activity has been sporadic. No production had been reported by 1960.

An 8-foot vein of massive white quartz containing very little scheelite crops out about 1 mile northwest of Teeters Peak. The vein is exposed by three bulldozer cuts and an inclined shaft, now inaccessible. A chip sample across the vein assayed a trace of gold and silver. No scheelite was observed under the short-wave ultraviolet lamp. Gouge and shattered vein material along the creek bottom may be indicative of postmineral faulting along and parallel to the vein, but faulting could not be confirmed. The southeastward extension of the vein west of Teeters Peak must nearly conform to the creek bottom, as quartz float can be found there through most of this distance. In the early days, gold-bearing float was reported in this vicinity and west of Teeters Peak, but gold has never been found in commercial quantity. The Waylett vein extension can be traced southeastward to Fisher Creek. Samples of vein material were "lamped" for scheelite, but none was found.

Most of the bulldozer trenching and all diamond drilling was done on the sheeted and sheared zone 3 miles northwest of Teeters Peak, mapped as an extension from the southeast. The exploration work there consists of twenty trenches, twenty-five vertical and inclined diamond drill holes to depths of 45 to 60 feet, and three pits.

Near the west tributary of Miller Creek (northwesternmost exposure) trenches have exposed two nearly parallel shear zones of undetermined width 300 feet apart. The zones and associated quartz veins strike generally N. 20° to 30° W. and dip 80° to 85° E. Within the sheared zone, quartz veinlets and breccia recemented with quartz contain scheelite. Evidence of two periods of premineral movement is observed at one bulldozer cut, where vein quartz has filled a small fault and also a portion of the displacing fault.

Scheelite is found as masses and small disseminated white blebs in quartz. The mineral cannot be megascopically identified without the aid of short-wave ultraviolet light. Small amounts of a gray mineral, believed to be tetrahedrite, have been reported in the veins.

The country rock in the vicinity of the northwestern prospect is gray calcareous argillaceous quartzite of the Wallace Formation. Some dark-and light-gray contorted dolomitic limestone is present in the area. Wallace bedrock strikes N. 20° to 30° W. and dips 40° to 80° NE.

The presence of "vein bending" near the footwall (west side) in contrast to undisturbed beds in the hanging wall (east side) suggests that a postmineral low-angle fault parallel to the vein within the sheeted zone has disturbed the attitude of the vein and the sedimentary rocks. Drag folds west of the vein near Teeters Peak suggest that a large low-angle reverse or underthrust fault dropped the west (footwall) side.

The sheeted zones have not been traced north of Miller Creek. These zones consist of numerous small veins and veinlets that may represent "horse tailing" or termination of structure.

Representative samples of scheelite-bearing quartz taken 1½ miles northwest of Teeters Peak assayed 0.22 percent to 0.68 percent tungsten oxide (WO_3). Selected specimens assayed as much as 3.72 percent WO_3. A channel sample across an 8.4-foot width in a sheared zone assayed 0.77 percent WO_3.

POTTER

The Potter prospect is about 2 miles west of Loon Lake and half a mile north of U.S. Highway 2, in southeastern Lincoln County. The property was acquired by the late J. K. Potter of Libby during the early 30's, and the mineral rights for an undetermined amount of homestead land was obtained by Mr. Potter during the middle 30's. The prospect was actively developed between 1937 and 1945. Surface buildings include a cabin, bunkhouse, and compressor building, which are in fair condition. No production has been reported.

The fissure vein is developed by an inclined shaft (caved) and a crosscut adit (partly accessible). The crosscut adit is driven to intersect the vein at a lower elevation.

At the collar of the shaft a vertical quartz vein strikes N. 50° W. and dips 30° SW. The structure is 2 feet wide at the surface, where it includes 1 foot of mineralized quartz and 1 foot of brecciated quartz and clay gouge. Vein sulfides identified are chalcopyrite and pyrite. Other vein minerals are quartz, malachite, and calcite. A channel sample of the quartz fraction assayed 1.26 percent copper, 2.8 percent iron, and traces of lead, zinc, and silver. The gouge and brecciated quartz assayed 0.90 percent copper, 2.20 percent iron, and traces of lead and silver. A selected sample from the adit dump contained chalcopyrite, pyrite, azurite, and malachite in a gangue of quartz and calcite. The sample assayed 1.42 percent copper and 1.30 percent iron. Mr. Potter reported that in a drift off the adit, discontinuous lenses of chalcopyrite as much as a foot wide assayed 20 percent copper. Jack Larue of Libby reported (personal communication) that one irregular lens of massive chalcopyrite seemed to widen beneath the base of the adit.

Country rock in the vicinity of the property is Libby light-gray quartzite and gray calcareous argillite striking N. 40° to 80° W. and dipping 30° to 35° SW.

KIRKPATRICK

The Kirkpatrick prospect is on the north side of Kavalla (Atlanta) Creek, a tributary of Wolf Creek in southeastern Lincoln County. In 1931, Mr. Kirkpatrick acquired the surface and mineral rights of the SE¼ sec. 15, originally the Marfield homestead. Surface and mineral rights to the SW¼ sec. 15 were at one time owned by A. O. Baumann, who sold the property to the J. Neils Lumber Company. Most of sec. 16 is state school land.

The property is not known to have produced any ore.

The prospect is developed by an 80-foot adit, a 35-foot shaft (now caved), a bulldozer cut several hundred feet long, and several pits. Kirkpatrick reported that a quartz-pyrite vein striking east(?) was intercepted in the shaft. Most development work was done between 1931 and 1933, but additional bulldozing and exploration were done in 1958 and 1959.

A vertical quartz vein 6 to 30 inches wide strikes west and intersects one 4 to 14 inches wide that strikes N. 70° W. Another flat-lying sulfide-bearing veinlet 2 inches wide parallels Prichard strata, which here are flat to gently dipping medium-gray and grayish-blue banded quartzite and quartzitic argillite that strike N. 22° W.

The east-west vein, developed by an 80-foot adit, has very sparse galena and pyrite in a gangue of white massive quartz and iron oxides. A chip sample across a 2-foot width at the face of the adit assayed traces of gold, silver, and lead.

The N. 70° W. vein, where exposed in a shallow pit within a bulldozer cut, is 1 foot wide but contains only minor amounts of hematite and limonite. The vein was not sampled.

Selected specimens from the "bedding veinlet" near the south end of the bulldozer cut contained pyrite, chalcopyrite, covellite, galena, sphalerite, and iron oxides sparsely scattered throughout, and assayed 0.20 percent copper, 5.40 percent combined iron oxides, and traces of gold, silver, lead, and zinc. Mr. Kirkpatrick reported that a sample from a pit on a hilltop above the bulldozer cut assayed 14.6 percent zinc, 8.4 percent lead, 3.2 ounces silver, and 0.005 ounce gold a ton.

BOULDER HILL

This prospect is on a grass-covered sparsely timbered slope east of Kavalla Creek, locally known as Boulder Hill. Two claims, the Hope and Boulder Hill, were relocated by Charles C. Strodtbeck in 1946. The property has been inactive for many years.

In 1894, prospectors reported a high-grade gold-quartz boulder; subsequently the main adit was opened about 20 feet east of the point where the boulder was found. In 1903 Knute Tideman and Charles Strodtbeck located two claims after finding additional gold-bearing quartz float in the vicinity. In 1906 a syndicate became interested in the property and subsequently leased the ground. The property was active only intermittently until 1939, but from 1940 to 1947, Strodtbeck extended two old adits and dug numerous trenches and pits in an effort to discover gold-bearing ore bodies in the quartz veins.

A 4-inch vein of iron-stained quartz exposed near the top of Boulder Hill strikes N. 70° W. and dips 85° SW. The country rock is Prichard argillite. The covered northwest extension of the vein on Boulder Hill is developed by two adits, now inaccessible, and by fifty pits and trenches, in which the vein was exposed at intervals of 30 to 50 feet for a distance of half a mile.

Vern C. Strodtbeck of Kalispell reported that the two adits on quartz veins are 50 and 500 feet long. The quartz vein in the 500-foot adit is as much as 18 inches wide, and averages 10 inches, but was lost at a fault near the face. Sections of this quartz vein assayed $5 a ton in gold and silver. Representative samples of quartz from the adit dump assayed 0.10 ounce gold and 0.04 ounce silver a ton.

STRODTBECK

The Strodtbeck prospect is in gently dipping Prichard beds on Redemption Ridge west of Little Wolf Creek. The three unpatented claims were relocated by Charles A. Strodtbeck of Kalispell in November 1931. Exploration work amounts to a 10-foot discovery shaft and several pits and trenches. In 1959 the prospect had been inactive for many years.

Several vertical parallel quartz veins 3 to 4 inches wide strike N. 60° to 65° W. and contain sparse galena, cerussite, anglesite(?), chalcopyrite, azurite, chrysocolla, and pyrite. Hematite and "limonite" fill vugs and occur as pseudomorphs of pyrite. The veins are in medium- and dark-gray argillite, which strikes N. 20° W. and dips 5° to 10° SW.

The axis of the Fairview anticline is a short distance east of the property. The southeast projection of the quartz veins intersects the axial trace of the fold at an angle of about 55°.

Reported production from the property amounted to one car of ore shipped prior to the relocation of the Great Northern Railway Company tracks to the Kootenai River in 1904. The width of the vein and the amount of work done seem insufficient to produce that much ore.

Selected specimens of dump material assayed 0.40 percent copper, 1.8 percent lead, 0.24 ounce gold, and 0.30 ounce silver a ton.

Vern Strodtbeck reported that half a mile east of this property is a prospect developed by a 30-foot vertical shaft on an 8-inch quartz vein. This prospect was not found during our reconnaissance mapping in the area.

RAVEN

The Raven and Lucky Mac groups each include six unpatented claims in the Rainy Creek district about 11 miles east of Libby. The claims were staked by J. D. Daniels, H. C. Daniels, and H. Daniels, of Volcour and Libby, in 1955. The property is 2 miles southwest of the Zonolite Company vermiculite operation. No production has been reported. Development at the Raven group amounts to a 20-foot adit and nine bulldozer cuts on a quartz-bearing sheared zone 8 to 25 feet wide, which strikes north and dips 60° E. In that part of the structure explored by the 20-foot adit, quartz is the most abundant mineral; some galena, cerussite, chrysocolla, malachite, tremolite, and jasper are present. A sample of the vein material assayed 1.6 percent copper.

Approximately a quarter of a mile east of the sheared zone is the parallel Lucky Mac vein exposed in two pits near the contact of syenite and Wallace country rock. Wallace strata strike north and dip 40° E. In order of abundance the minerals in the vein are quartz, galena, fluorite, and very sparse autunite(?). Radioactive specimens are found in the pits, and Daniels stated that radioactivity can be traced on surface for a distance of 1,500 feet along the strike of the vein.

Selected vein specimens assayed 17.0 percent lead and 0.75 ounce silver a ton. Daniels reported that a specimen from the vein assayed 7.5 percent zirconium oxide.

HATHAWAY

In the early 1900's, George Hathaway and others developed a small copper-bearing quartz vein on a north-trending ridge between Reinshagen Gulch and Canoe Gulch about a mile north of Jennings. The prospect is believed to be on ground owned by the Northern Pacific Railway Company. It is accessible by State Highway 37 and a U. S. Forest Service road to within one-third mile of the adit. No ore has been produced from the property.

Development work includes an accessible 300-foot adit and crosscuts totaling 150 feet driven perpendicular to the vein. An open cut exposes the vein 150 feet north of the adit portal.

The vertical vein is 10 to 12 inches wide at the outcrop and even narrower at the depth of the adit level. It strikes N. 74° E. Minerals present at the outcrop in order of abundance are quartz, chalcopyrite, malachite, galena, and pyrite. In the adit the vein is barren of sulfides.

The prospect is in red-gray-purple argillaceous sedimentary rocks, which strike N. 15° W. and dip 38° E. These rocks may represent a small remnant of Striped Peak strata overlying Wallace beds, but on the geologic map the strata are mapped as the Wallace Formation.

A normal sample across the vein in the pit assayed 4.25 percent copper, 0.50 percent lead, 6.30 percent iron, a trace of zinc, and 0.90 ounce silver a ton.

KENNEDY

During the middle 1950's Russell Deist, Lloyd Gould, H. P. Reinshagen, Jr., and Les Bloom located a group of claims on the north side of Kennedy Gulch approximately 1¼ miles east of State Highway 37. At individual locations abnormal scintillator readings indicated the presence of radioactive material associated with igneous rocks.

The claims were subsequently explored by several bulldozer cuts, but mineable uranium ore was not found. Radioactivity in the area may have been caused by sparse autunite in the dike and in the surrounding Wallace country rock. Selected specimens were reported to assay as much as 0.20 percent U_3O_8 (uranium oxide). (Personal communication, H. P. Reinshagen, Jr.)

Bulldozer cuts exposed parts of a diorite dike a half mile long and 50 to 100 feet wide. Locally it is stained by small amounts of iron and copper oxides. Pyrite crystals as large as one-quarter inch are sparsely scattered throughout.

Selected samples at two locations (LB-5 and 6, Pl. 1) assayed 0.60 and 0.26 percent copper respectively, and traces of silver and zinc. Neither sample was radioactive.

The ground has been relocated by Russell Deist and Lloyd Gould.

OTHER PROSPECTS AND VEINS

A 12- to 18-inch vein 2 miles northwest of Fairview crops out for a distance of 40 feet. The white massive quartz contains vugs filled with hematite and limonite. The vein cuts medium-dark-gray Prichard argillite, which strikes north and dips 14° E. The quartz vein trends N. 80° E., dips 85° N., and is explored by a 3-foot pit. Vein material assayed a trace of gold and silver.

A quartz vein cropping out about a mile west of Betts Lake is 6 to 30 inches wide. The vein is vertical and strikes N. 70° W. White vuggy iron-stained quartz showed no sulfide minerals. The vein, exposed in two shallow pits, cuts medium-dark-gray quartzitic argillite of the Prichard, which strikes N. 15° W. and dips 6° to 12° W.

Other small quartz veins were mapped along Wolf Creek road about a mile east of Richards Creek. Two parallel east-striking vertical quartz veins were mapped 1,000 feet southeast of Fisher Mountain, about 2½ miles west of the mouth of Wolf Creek. The veins are about a foot wide and are separated by 50 feet of country rock. One vein, exposed in a 6-foot pit, contains quartz and sparse chalcopyrite, pyrite, tenorite(?), and azurite. Country rock is mud-cracked medium-gray argillite and calcareous limestone of the Wallace Formation. Selected specimens from the discovery pit assayed 1.20 percent copper and traces of lead and silver.

A prospect near the Kootenai River about a mile west of Gopher Hill is on the side of a steep cliff several hundred feet east of the Canyon Creek road. The country rock is Ravalli quartzite and argillite, which contain disseminated biotite and magnetite. Samples of material assayed 0.54 percent copper and traces of lead and zinc.

A quartz vein of undetermined width (possibly a foot or more) was observed a mile west of the Zonolite Company open pit on the northeast side of a small ridge. The trend of the vein or veins is difficult to determine, as outcrops are scarce and the hillside is covered with quartz float. The vein is explored by four pits. Small amounts of galena and malachite are associated with dump material. Selected dump specimens assayed 0.40 and 0.34 percent copper and traces of lead and silver.

Quartz veinlets are associated with a meta-diorite sill, which crosses the Kootenai River 2 miles northeast of Libby. A sample of vein material assayed 0.16 percent copper, 11.80 percent iron, 0.60 ounce silver a ton, and traces of gold, zinc, and manganese.

A short adit in Cambrian(?) limestone was noted on the east side of Swamp Creek 14 miles southeast of Libby and several hundred feet north of U. S. Highway 2. The dump is visible from the road. The adit was driven in a northerly direction along joints or small faults. No evidence of mineralization was seen in the adit.

Another adit, a short distance east of Fritz Peak, has been reported but was not found.

A 65-foot vertical shaft is sunk on iron-stained fault breccia on Sullivan Peak half a mile north of the head of Tamarack Creek. According to reports the headframe was erected and shaft sinking contracted in 1924, by a stock company formed for this purpose. No other information concerning the venture was obtained. The company was reported to be looking for copper, but the dump contains pyrite.

About 1½ miles south of the Tideman placer, two unpatented claims (Barbara and Mastadon) are located on a 5-foot dike that intrudes Belt rocks and is exposed for a distance of 100 feet or more. Development consists of a 15-foot shaft and several cuts and pits. The dike contains some galena and sphalerite and traces of gold and silver. There has been no production from the property.

A 2-foot quartz vein on Mt. Rogers 3 miles north of Loon Lake strikes N. 80° E. and is vertical. Libby beds in the area strike N. 15° W. and dip 40° SW. A sheet of gouge and breccia resulting from postmineral faulting parallels the south side of the vein.

Samples from a 6-inch quartz vein 2 miles north of Horseshoe Lake assayed only traces of gold and silver. Quartz float from veins was observed at two localities in the Swamp Creek area. Along a road cut east of U.S. Highway 2 and 4 miles southeast of Detgen Creek, sparse chalcopyrite, siderite, and ankerite(?) were found in medium to large pieces of quartz float. Along the east flank of the valley of Swamp Creek about a mile north of Reinhart Creek is quartz-bearing talus as much as 10 inches thick, which contains chalcopyrite, siderite, and ankerite. Specimens of float assayed 0.46 percent copper, 0.50 percent lead, 1.50 percent manganese, 2.6 percent iron, and a trace of zinc.

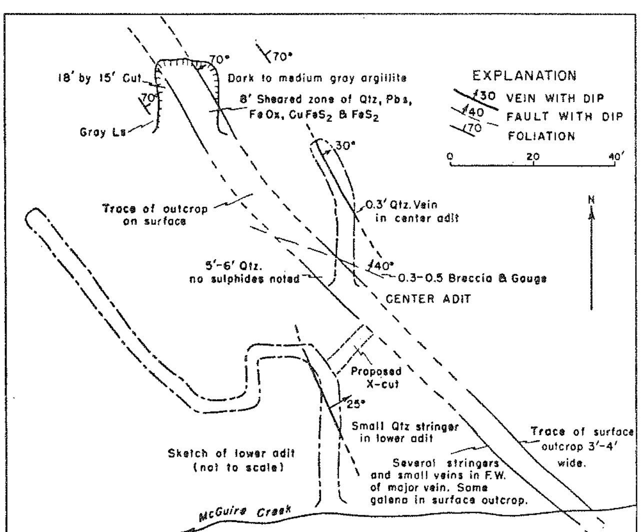


Figure 31.—Surface plan of Second Chance prospect, Ural area, Lincoln County.

Other quartz veins 2 to 4 inches wide crop out on the north valley wall midway up Snell Creek and along a ridgeline north of the headwaters of Tensaw Creek. At both localities the white massive vein quartz contains vugs filled with oxides of iron and manganese.

URAL AREA

SECOND CHANCE

The Second Chance prospect (formerly the McGuire property) is about a mile up McGuire Creek on the north slope of the valley. The property was originally located in the early 1900's by a prospector named McGuire. One claim was relocated by Marion Fishel of Kalispell in 1958.

Bedrock is the upper part of the Prichard Formation adjacent to the contact with the overlying Ravalli. A sheared zone as much as 8 feet wide strikes N. 30 W. and dips 70° N.E. (Fig. 31). It contains several veins 1 to 3½ feet wide. The smaller veins are adjacent to the footwall of the larger structure. Country rock west of the sheared zone is gray calcareous argillite, whereas that on the east side is dark- to medium-gray argillite. In this area the sedimentary rocks strike N. 35° W. and dip 70° NE. Minerals in the 3- to 8-foot sheared zone include milky quartz, argentiferous galena, chalcopyrite, pyrite, and iron oxides.

The property has been developed by a pit 18 by 15 by 3 feet and by two adits, 600 feet and 40 feet in length. The lower adit follows a quartz stringer for a short distance but then trends west of the sheared zone and continues in barren rock for 570 feet. The 40-foot adit intersects a quartz vein at the portal and continues on a 4-inch quartz stringer in the hanging wall for a distance of 15 feet. The cut indicates that a 2-foot fault in the footwall parallels the mineral zone (personal communication, Marion Fishel). The fault seems to strike northwest and contains both gouge and breccia.

Mr. Fishel reported that grab samples assayed 15 percent lead and selected specimens assayed 42 percent lead and 7 ounces silver a ton. The writer collected a channel sample across a 3½-

foot vein in the pit, which assayed 9.6 percent lead, 0.12 percent copper, and 3 ounces silver a ton.

HANSEN

The Hansen prospect is about a quarter of a mile east of the Burma road and 2½ miles east of Roosville in northern Lincoln County (Fig. 37). The property was located by Ben Hansen of Rexford in the early 1960's. An adit 57 feet long follows a sulfide-bearing quartz vein (Fig. 32), which strikes N. 18° W. and dips 80° to 82° SW. Country rock is Purcell Lava. Vein width ranges from 3 to 6 inches, and near the face of the drift the vein splits into two segments, each about 1 inch thick. Abundant vein minerals are quartz, chalcopyrite, barite, and pyrite; minor constituents are malachite, chalcanthite, tenorite, cuprite, and bornite (?).

Specimens selected from an ore stockpile assayed 12.75 percent copper, 0.55 ounce silver, and 0.002 ounce gold a ton.

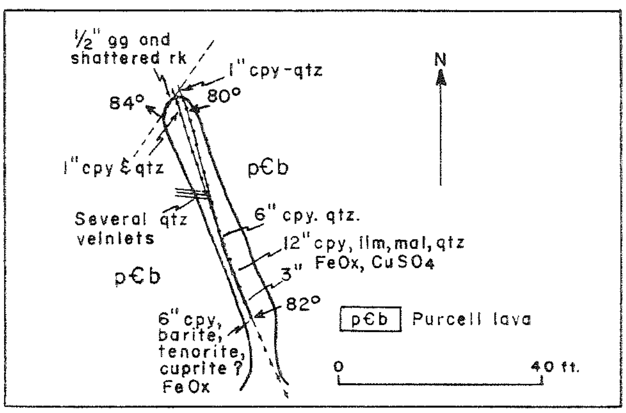


Figure 32.—Geologic sketch of Hansen adit, Ural area.

HOYT (NORTH STAR) GROUP

The Hoyt property, about a mile east of Warland, consists of seven claims and a fraction located on the Warland alaskite stock and a patented timber claim of 120 acres. The mineral and timber claims are owned by Mrs. Carol Tallmadge of Libby, Montana. Production from the property has been small, possibly a few hundred tons. According to report, a mill was constructed.

Development work includes a 170-foot inclined shaft (inaccessible), a pit 5 by 15 by 10 feet, and two bulldozer cuts near the ridge top at the southeast end of the stock, and a 180-foot adit (now caved) and 20-foot inclined shaft on the northwest side of the stock. A few other workings are reported north of the intrusive body, but they were not visited.

Northwest of the stock the short incline reveals a 14- to 16-inch quartz vein stained with malachite. The vein strikes north and dips about 34° E. The 180-foot adit was started about 50 feet below the incline and was driven eastward. A sample across the 14-inch vein at the collar of the shaft assayed 0.10 ounce gold and 0.10 ounce silver a ton. About 6 inches of gouge on the footwall of the structure assayed traces of gold and silver. Other veins were reported to assay $8 to $10 a ton in gold.

Veins at the southeast end of the granitic stock strike about N. 10° W. and dip 30° E. Mrs. Tallmadge reported that the quartz vein in the 170-foot shaft assayed $30 to $35 a ton in gold. The bulldozer cuts are on a 10-inch vein striking N. 20° W. and dipping 67° SW.

Some equipment, including an old compressor, was observed at the 170-foot shaft, and two cabins, a collapsed compressor house, and an ore bin were noted at the 20-foot shaft.

KENELTY

Gerald and Garth Kenelty of Libby staked two claims near the head of Ural Creek in August 1960. Small stringers of quartz ¼ inch to 6 inches wide can be traced for about 30 feet in a sheared zone. The quartz contains some specular hematite and other iron oxides. The sheared zone trends N. 45° E. across the Ravalli quartzite, which strikes north and dips 10° to 28° E.

A representative sample from the veins assayed traces of gold and copper and 0.10 ounce silver a ton.

BIG CREEK

The portal of the adit on the Big Creek property is about 150 feet above the junction of the North Fork and South Fork of Big Creek and about 100 yards west of the Forest Service guard station. The adit was driven 300 feet on a small quartz vein in the Prichard Formation. There was no production from the property, and its present status is unknown.

The vein, occupying a small fault just west of the major shear zone of a high-angle reverse fault, pinches and swells; width ranges from 1 inch to 18 inches. For the greater part of its length the quartz vein is barren, and near the face of the adit it pinches out entirely. Minerals observed in the narrow parts of the vein were galena, marcasite, and minor amounts of sphalerite, pyrrhotite, and native silver. A sample taken along a 25-foot length of the vein where it is only 3 inches wide assayed 7.3 percent lead, 1.7 percent zinc, 0.1 percent copper, and 5.1 ounces silver a ton. Small amounts of galena, pyrite, and siderite were noted in a prospect pit excavated on the quartz vein.

BIG CREEK EXTENSION

High on the ridge just north of the Big Creek property, two short adits have been driven on a barren quartz vein. The vein is in the main shear zone of the north-trending fault that crosses the Big Creek property and is strongly sheared by renewed movement along the fault. Specimens of quartz found at a cabin a short distance from the vein contained traces of gold, silver, and lead.

OTHER PROSPECTS AND VEINS

A short adit in the Purcell Lava about 2 miles northeast of Rexford revealed small masses of barite and calcite near the portal. No quartz or sulfide minerals were observed, however.

In a road cut on the South Fork of Young Creek road about 3½ miles west of Tooley Lake, a small pit exposes chalcopyrite, malachite, and tenorite disseminated throughout coarse-grained sandstone interbedded with argillite in the upper part of the Ravalli Group. A grab sample assayed 0.5 percent copper, 0.6 ounce silver a ton, and a trace of gold.

On the south side of Young Creek, 3½ miles east of Robinson Mountain, pieces of vein quartz containing traces of galena, chalcopyrite, pyrite, and native silver were noted. The quartz pieces, 2 to 4 inches across, seem to have come from a shear zone exposed in the road cut, but the vein itself was not observed. A selected sample of quartz contained 0.1 percent copper, 0.8 percent lead, 0.5 ounce silver, and 0.005 ounce gold a ton.

Road cuts on the north side of the east-trending ridge north of Caribou Creek and 2 miles east of Caribou Peak expose several small north-trending quartz veins that average less than 12 inches wide and cut the Shepard Formation. Ore minerals noted were traces of galena, chalcopyrite, pyrolusite, and iron oxides. No veins that were sampled contained more than 1 percent manganese. The main vein trend is north to N. 15° E. Another set of veins trends N. 65° to 85° W. and is vertical or dips steeply southwest. The only development work noted was a 10-foot adit on two closely spaced parallel north-trending 6- to 8-inch quartz veins containing pyrolusite and iron oxide. The work was reported to have been done by Jim Hubbard about 1900. The area is shown in Figure 33.

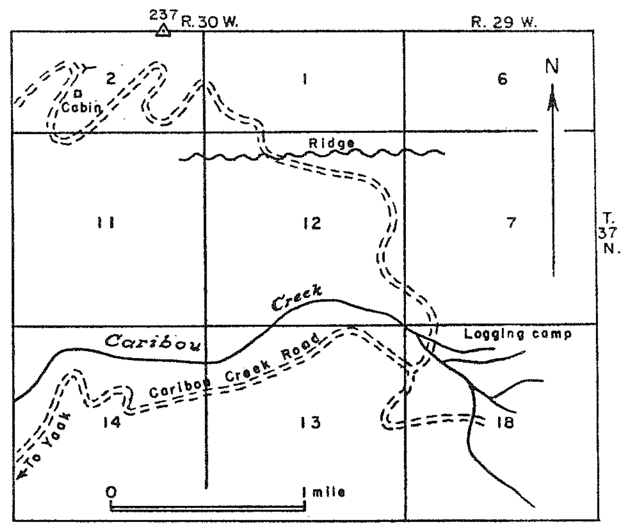


Figure 33.—Sketch of Caribou Creek area, northwest of Robinson Mountain, northern Lincoln County.

Exposed at the top of the lower flow of the Purcell Lava in the glacial cirque wall just west of Geneva Lake is a 6- to 18-inch zone of lava and quartzitic argillite containing abundant magnetite octahedra. A grab sample contained 14.2 percent FeO, 41.5 percent Fe_2O_3, and 0.26 percent TiO_2. Part of the magnetite may be in the oxidized top of the lava flow. The deposit is too small to warrant exploitation.

At the J. D. Daniel ranch at Volcour and about 50 feet east of the Volcour road, a quartz vein several feet wide cuts Prichard argillite. The vertical fissure vein strikes N. 50° to 60° E. and contains considerable chlorite and iron oxides.

Several quartz veins containing chlorite and sericite crop out on the ridge southwest of Lost Soul Mountain. These veins are 1 to 6 inches wide and strike N. 70° W.

Some galena was reported (1962) in a well dug on the Jim Meeker ranch 2 miles northeast of Rexford. Mr. Meeker has the mineral rights to the property.

NORTHERN THOMPSON FALLS AREA

VIKING

The Viking property was originally located by Mark Fowler in 1934, and has been operated under the management of the Viking Mining Company as the Viking mine and the Gold Hill group. The property, in southeastern Lincoln County, is near the head of Silver Butte Creek 2 miles north of Silver Butte Pass (Fig. 34). The property has long been inactive and its present status is unknown. Data on development, ore reserves, and grade of ore have been obtained from a private report written by U. M. Sahinen, dated August 1946.

In 1946 the property consisted of three claims, which had been surveyed for patent (Sur. No. 10,755) but not yet patented, and a mill, which was built in 1938, abandoned before 1946, and collapsed by 1961. One surface building and the ore bin remained standing.

The Viking mine has been developed by 2,000 feet of drifting and crosscutting from five tunnels (Fig. 35). Only the lower one (Tunnel 1) is accessible, and that for a distance of only 175 feet, although Sahinen reported this tunnel as 240 feet long. Tunnel 2 (above No. 1) was driven as a crosscut for a distance of 70 feet and intersected the vein at 30 feet. A 250-foot drift explored the vein, which is displaced at both ends by faults, which strike northwest and dip southwest. Tunnel 4, above No. 2, was inaccessible in 1946; Sahinen reported no ore in this tunnel. No. 5 tunnel is 60 feet above No. 2 and involved about 680 feet of crosscutting and drifting to and along the vein. Tunnel 3, on Gold Hill No. 3 claim, was driven through barren rock for a distance of 350 feet. Tunnel 5 was the main working level and produced most of the ore mined by the Viking Mining Company. A quartz-vein outcrop south of Tunnel 5 follows the contour of the hill and was stoped to the surface for a length of 175 feet.

Five fissure-filled bedding veins consist of gold-bearing quartz containing galena, chalcopyrite, pyrite, limonite, and hematite; their thickness ranges to 22 inches. Sahinen reported that the available ore had been mined out except for small uneconomical blocks of milling-grade ore. A discovery cut 600 feet southwest of Tunnel 3, however, contained a 22-inch quartz vein assaying $19.60 in gold and 0.06 ounce silver a ton.

The northwest-striking quartz veins dip 33° to 45° NE and are displaced by en echelon segments of west-northwest faults that dip southwest (Fig. 35). The better ore, in part free milling, was mined from the zone of oxidation, above the water table.

Sandvig (1947, p. 64) stated that during excavation of the millsite a metadiorite sill containing extensive quartz veinlets was discovered. One channel sample across the sheeted zone assayed $14 a ton in gold.

The workings are in very light gray magnetite-bearing quartzite, light-gray quartzitic argillite that weathers medium to medium-light-gray, and blue-green thin-bedded and medium-bedded soft argillite of the Ravalli. The beds strike N. 35° W. and dip 45° NE. The Prichard-Ravalli contact is believed to be a short distance southwest of the workings.

KING

The King mine, formerly known as the Silver Butte, is at the head of Silver Butte Creek in southeastern Lincoln County. It was discovered in 1887 and was first operated by the Kentucky Vermillion Company. A fire destroyed all buildings, including a 150-ton mill constructed at a cost of $150,000 (Calkins and MacDonald, 1905, p. 105). Reports indicate that the property was idle for some time prior to 1905 and between 1910 and 1943. In 1943 the patented claims were owned by F. O. Berg of Spokane.

In 1943 the Silver Butte Zinc-Lead Mining Company was incorporated, with William Curts as president, and by 1946 $100,000 had been spent on development (Spokane Spokesman Review, June 30, 1946). In the 1950's the property was sold for taxes and the newly constructed 80-ton

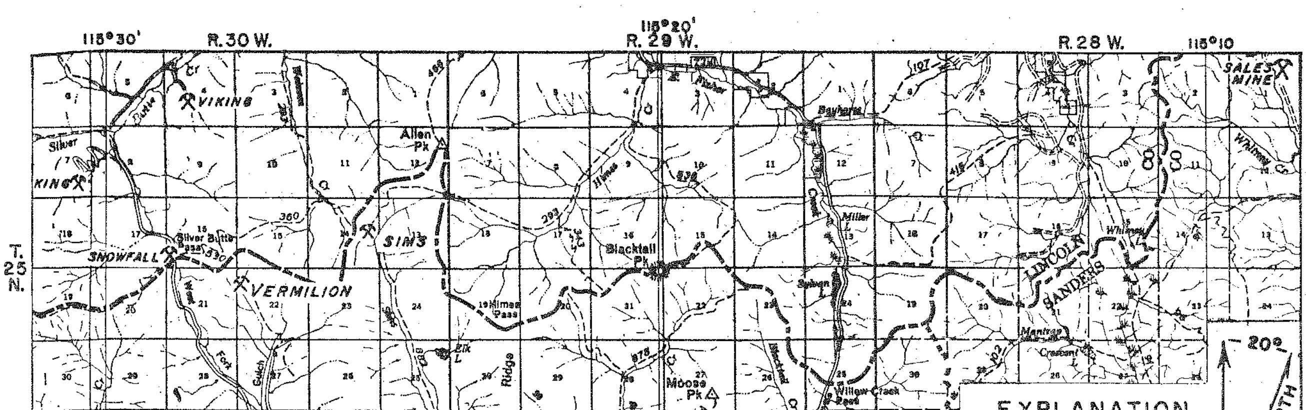


Figure 34.—Map showing location of mining properties in the Cabinet Mountains, northern Thompson Falls area, Lincoln and Sanders Counties.

flotation mill was dismantled. The property has since been inactive, and all buildings have been destroyed or collapsed. The holdings comprise ten patented claims, two patented millsites, and twenty-one unpatented claims, a total of 220 acres of patented ground and 430 acres of un-

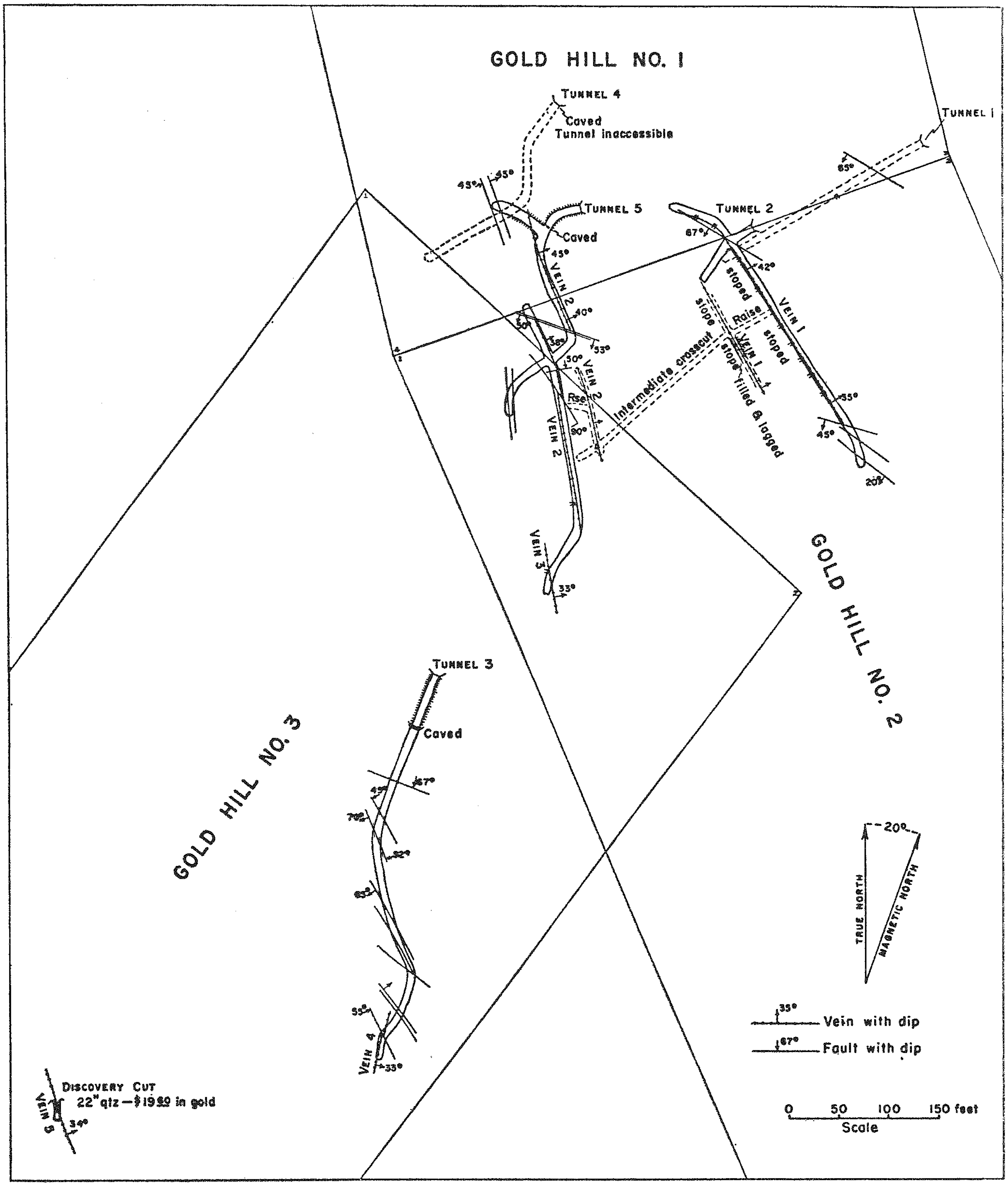


Figure 35. Workings on Gold Hill claims, Viking mine, northern Thompson Falls area, Lincoln County.

patented ground.

The mine is developed by four adits totaling 4,300 feet; only two of the adits are now accessible. A 110-foot raise connects two upper tunnels. The quartz vein strikes N. 60° W. and dips 30° SW. It averages about 10 feet in width. Country rock is gray and blue-gray banded Prichard argillite. Vein matter is white quartz that contains galena and small amounts of pyrite, chalcopyrite, and sphalerite. The outcrop of the quartz vein on the ridge northeast of the lower workings is reported to be 30 feet wide. Albert J. Koebel and son of Sandpoint, Idaho, explored by diamond drilling in 1947 (Spokane Spokesman Review, July 7, 1947).

The first shipment of concentrate from the mill was valued at $2,300. In 1947, mill heads were running more than $30 a ton; ratio of ore to concentrates was 7 to 1; the zinc concentrate assayed 45 percent zinc and 7 ounces silver a ton; and the lead concentrate assayed 59 percent lead and 42 ounces silver a ton (Spokane Spokesman Review, June 30, 1946). Selected dump samples from the upper accessible adit assayed 18.50 percent lead, 0.01 ounce gold, and 9.10 ounces silver a ton.

VERMILION

Near the head of Lyons Gulch about a mile southeast of Silver Butte Pass in northern Sanders County is the Vermilion mine, formerly known as the Carpenter property. It was described in an earlier report (Crowley, 1963, p. 51) as the Silver Butte. In this report, the property formerly known as the Silver Butte is described as the King. The property consists of six patented claims, named the Dominion group, some of which cross the Sanders-Lincoln County line into the valley of a tributary of Silver Butte Creek. T. H. Erickson of Moses Lake, Washington, owns the property. A narrow but passable road follows Lyons Gulch nearly to the lower camp and millsite. An impassable wagon road follows the left (west) tributary for 1 mile to the workings. A 50-ton mill, from which the milling equipment has been removed, is situated at the lower camp on the east side of Lyons Gulch.

Development work amounts to about 1,650 feet of adits, drifts, and crosscuts, and 145 feet of raises from the upper accessible adit (Fig. 36). The distance from the portal to the first raise on the ore shoot is approximately 800 feet. About 520 feet of drift follows the bedding-plane vein to the most northern face. A lower adit, of unknown length, is caved at the portal.

From the portal almost to the first raise, the upper adit follows a discontinuous quartz vein bearing sparse sulfide. The vein is 3 inches wide, strikes northwest, and dips northeast. From the adit a north-striking adit spur penetrates barren Prichard argillite for 250 feet. At the first raise the sulfide-bearing quartz vein is about 6 feet wide. It

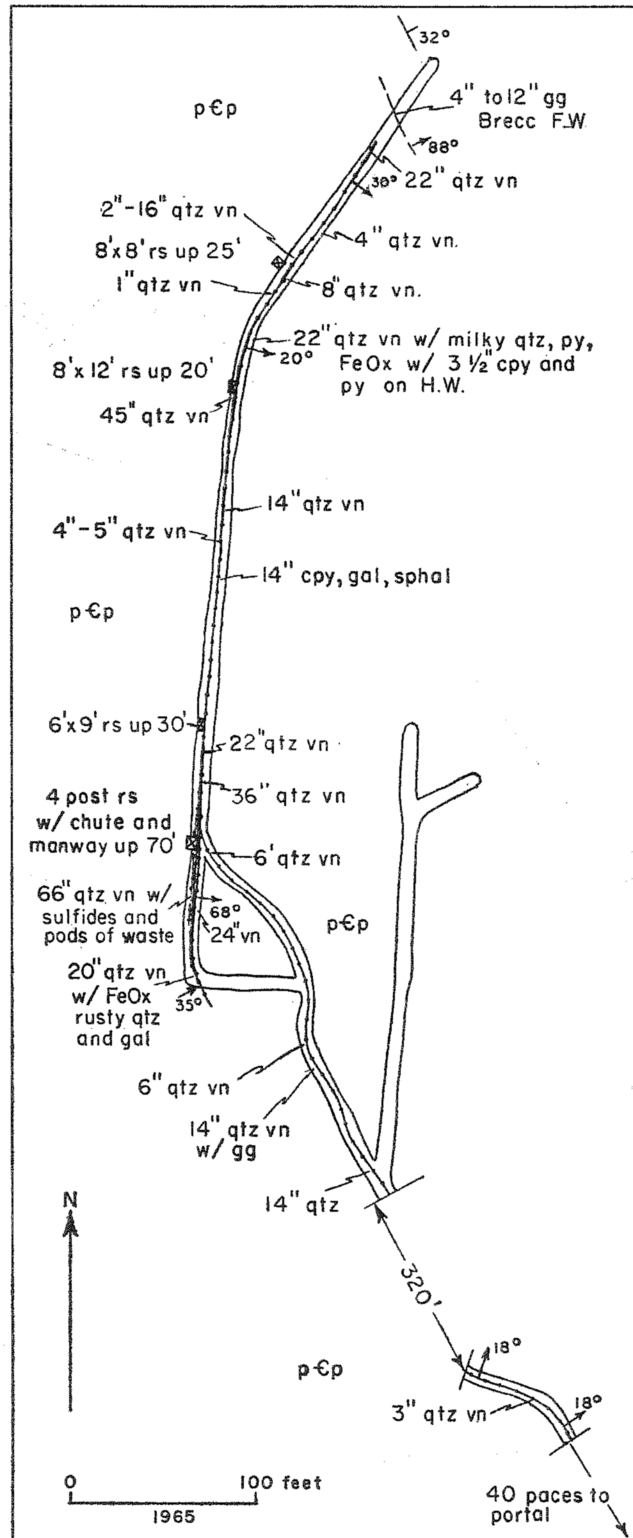


Figure 36.—Geologic map of Vermilion upper adit, northern Thompson Falls area, Sanders County.

pinches and swells from 4 inches to 72 inches but averages 25 inches. The main vein approximately parallels the strike but crosscuts the dip of the argillite; its strike ranges from N. 5° E. to N. 35° E. and its dip ranges from 20° to 68° SE. Four raises 20 to 70 feet high explore the vein above the drift.

Vein minerals in order of abundance are massive white quartz, pyrite, chalcopyrite, tetrahedrite, sphalerite, galena, and bornite. Sparse sulfide vein minerals occur as pods and masses in white massive quartz. Iron oxides are common vein components. Crowley (1963, p. 52) reported that a muck-pile sample at the foot of a raise assayed 1.3 percent lead, 1.3 percent zinc, 0.28 percent copper, 0.05 ounce gold, and 0.4 ounce silver a ton.

Country rock is Prichard argillite, which at the northernmost face strikes N. 22° W. and dips 32° E. Bedding at the portal of the accessible adit strikes north.

A selected sample from ore stockpiled on the upper dump assayed 2.2 percent lead, 2.0 percent zinc, 1.1 percent copper, 0.18 ounce gold, and 2.0 ounces silver a ton.

SALES

The Sales mine is on a north tributary of Whitney Creek near the Lincoln-Sanders County line about 8 miles south of Horseshoe Lake. The country rock is in the Libby Formation, which here consists of light-gray, light-brown, yellow, and green argillite, striking N. 20° to 40° W. and dipping 80° to 85° SW. The property has been inactive at least since 1960.

A caved adit enters the hillside a short distance above creek level, and for a distance of 1,000 feet along a ridge that trends southeast from this adit, nine bulldozer cuts spaced about 100 feet apart expose copper carbonate and copper silicate minerals in a nearly vertical fractured zone that trends S. 20° E. The first five cuts south of the adit (a distance of about 600 feet) contain sparse chrysocolla and azurite and very sparse malachite. The other four cuts contain little or no copper minerals, although the fracture zone was exposed in all cuts reaching bedrock. Southeastward the zone decreases in width and in intensity of fracturing. Material in the first cut, believed to be representative of the first five, assayed 0.82 percent copper, 0.30 ounce silver, and 0.001 ounce gold a ton across the 4-foot fractured zone.

Chrysocolla is found as blebs and masses in shattered argillite, whereas azurite forms a surface coating on shear planes within the zone. In fresh argillite, small stringers and elongated masses of cupriferous pyrite (?), chalcopyrite, pyrite, galena, sphalerite, and possibly some chalcocite were noted within the structure. The source of the sulfides could be an intrusive body below the fractured zone. Surface water circulating within the fractured zone has converted the copper-bearing sulfides to carbonate and silicate minerals. The operators have attempted to leach the low-grade material; leaching equipment, including a precipitating tank, and a hammer mill remain at the site.

In 1960 the owners of the property were listed as Mr. and Mrs. Gordon Sales and Ruth Sales, P. O. Box 464, Kalispell, Montana.

SIMS

The Sims prospect is near the divide between Sims Creek and Waloven Creek 2½ miles east of the Silver Butte Pass. Development includes a 100-foot adit and a caved adit (?) and trench. Country rock in the adit is grayish-green siliceous argillite of the Wallace Formation, which strikes northeast and dips southeast.

Some pyrite, chalcopyrite, and arsenopyrite (?) as veinlets and disseminations in white massive quartz and carbonate gangue were noted on adit dumps. Disseminated chalcopyrite and quartz were identified in dump rock excavated from the trench and from nearby outcrops. The extent of disseminated copper minerals in the siliceous and calcareous argillite should be further investigated. The ground was relocated in 1964.

A grab sample from the trench a short distance northwest of the adit assayed 2.85 percent copper, 2.25 ounces silver, and 0.003 ounce gold a ton.

SNOWFALL

The Snowfall prospect is about a quarter of a mile north of Silver Butte Pass and 1½ miles southeast of the King mine. The property, which consists of one unpatented claim, was relocated in May 1955 by Clyde Roark and Blaze and John Echo. The original Snowfall workings consisted of two or more adits, now caved, one of which is east of the road. Chalcopyrite in milky white quartz was observed on the dump.

Development west of the road includes an adit (caved) and a discovery pit 20 by 10 by 6 feet. An east-striking vertical 8-inch vein in the discovery pit contains chalcopyrite and pyrite in a gangue of quartz. Sparse chalcopyrite and pyrite in quartz-siderite gangue were found on the dump of the caved adit. The prospect is near the Prichard-Ravalli contact. A grab sample of vein material from the discovery pit assayed 1.00 percent copper, 0.03 ounce gold, and 2.20 ounces silver a ton.

GOLD KING

The Gold King prospect, consisting of one unpatented claim, is on the north side of Vermilion River road, a short distance northwest of the Ajax placer and west of the mouth of Lyons Gulch. The claim was located by Ed Moreland in 1949 and relocated by Phil F. Leison in February 1961. There has been no production from the property.

A 1-foot quartz vein, developed by a 30-foot adit, contains small amounts of galena, chalcopyrite, sphalerite, and pyrite. It strikes N. 37° W. and dips 50° NE. A postmineral fault, marked by about 1 inch of gouge, cuts the vein. Drag folding in Prichard argillite on the footwall indicates that it is a normal fault.

Albert Thayer reported that a galena vein a few inches wide, cropping out a few hundred feet northeast of the adit, has been covered by bank sloughing.

MARTIN

The Martin prospect is 1 mile southeast of Dad Peak in Sanders County. The property is on a vein that strikes N. 20° W. in Wallace country rock. The weakly mineralized structure is east of and parallel to the Rock Lake fault. The property was not visited during the investigation.

PRICE

Approximately half a mile southeast of Rock Lake is the Price prospect. Gibson (1948) reported that the property consists of twelve unpatented claims at the head of Rock Creek. Exploration work amounts to an open cut and a crosscut adit. The cut exposes the Rock Lake fault, a vertical northwest-striking shear zone cutting Ravalli quartzite. At a lower altitude, the crosscut adit was advanced N. 20° E. for 343 feet but did not reach the fault zone (Gibson, 1948). The shear zone contains some partly oxidized pyrite and a few thin seams of galena.

On the southwest side of Rock Lake in a disturbed area near the Rock Lake fault, small veinlets and disseminated grains of sphalerite, galena, pyrite, and chalcopyrite are exposed in open cuts.

UNDEVELOPED SURFACE VEINS AND OTHER PROSPECTS

A 38-inch white quartz vein, striking N. 65° E. and dipping 84° NW., and a 15-foot sheared and sheeted zone containing quartz veins ¼ inch to 1 foot wide are exposed in bedrock cuts on the J. Neils-Bay Horse Creek road between East Fisher River and McGinnis Creek. The vertical sheeted zone strikes east. On an upper logging spur some red-brown limonite is associated with a 3-foot quartz vein.

Several bulldozer cuts on the east side of Miners Gulch, a tributary of Vermilion River, expose Ravalli quartzite stained with azurite and malachite. The bulldozing was done in 1956 or 1957. To the southeast, a zone of copper-bearing fractures a fraction of an inch thick occur in Ravalli quartzite.

EUREKA DISTRICT

INDEPENDENCE

The Independence copper property is on the north side of Indian Creek in the Whitefish Mountains northeast of Eureka (Fig. 37). It is reached by a 3½-mile trail from the mouth of Indian Creek. The claims were located by Edward Boyle of Eureka in 1892, and in 1960 the property was owned by the late E. J. Strasburger of Butte.

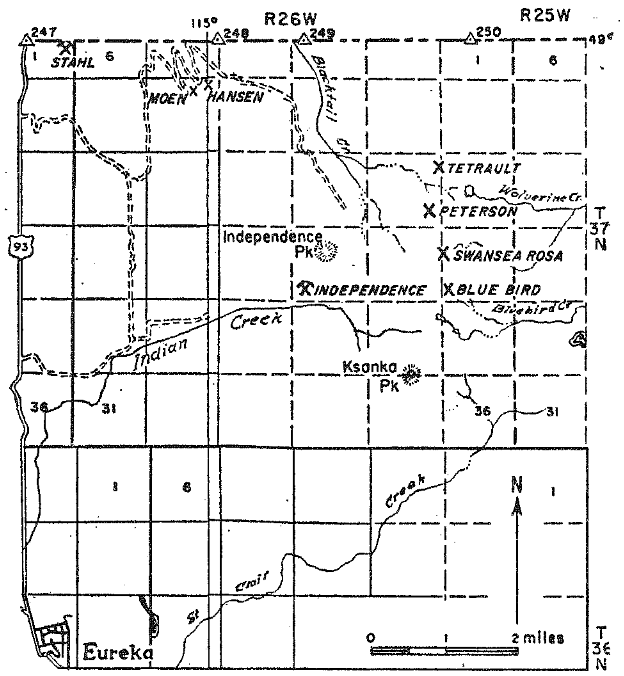


Figure 37.—Map showing location of properties in northern Whitefish Range, Eureka district, Lincoln County.

The property includes the Independence patented claim (MS 4421) (Fig. 40) and five unpatented claims, including the Dickey Lode, Safety Lode, Pearl, Liberty, and National Lode. The Little Willie Lode described in earlier reports is now the Pearl Lode. No production has been reported from the property.

The group is developed by several pits and trenches and six adits of which the lower adit (No. 3) 1,145 feet long, is still accessible. Adits 1 and 2 are respectively 370 and 326 feet in length (Fig. 38). A 50-foot adit on the Liberty claim is

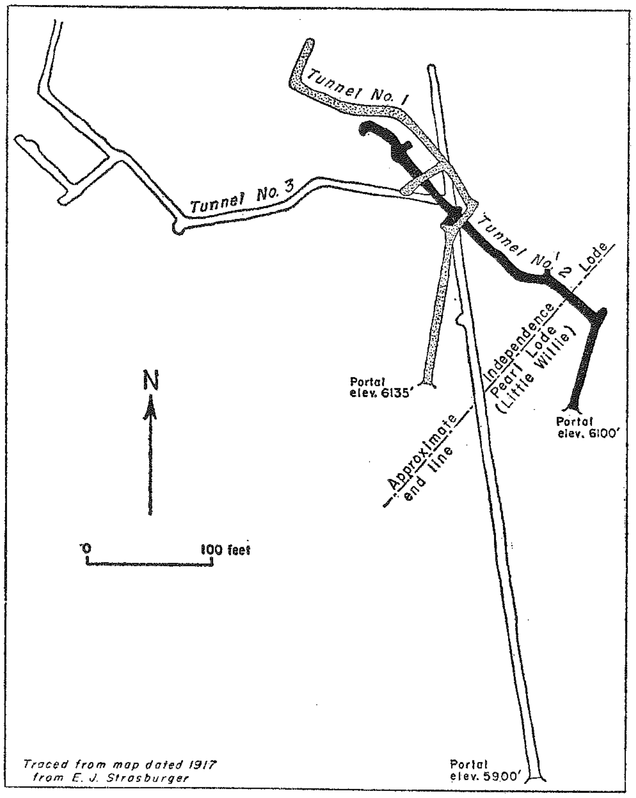


Figure 38.—Composite plan of workings, Independence mine, Eureka district.

also still accessible. Two other caved adits and three shallow pits were observed on Liberty ground.

Calcite-chalcopyrite vein material was intersected in the upper (No. 1) and middle (No. 2) adits on the Independence claim. In the lower adit (No. 3), a 17½-foot vein, the walls of which are poorly defined, strikes N. 35° W. and dips nearly vertical (Fig. 39). The vein contains chalcopyrite, calcite, pyrite, and iron oxides. The vein cuts the Purcell Lava, which is between the Piegan and Missoula Groups. Piegan strata (Siyeh) below the Purcell are mud-cracked, medium-gray and banded gray-green, slightly calcareous to noncalcareous argillite and quartzite, which strike N. 49° W. and dip 9° to 43° NE.

The 50-foot adit on the Liberty claim crosscuts a 6-inch vein near the portal. The quartz vein strikes N. 50° W. and dips 65° E., and it contains small amounts of malachite and pyrite. The adit crosscuts a second quartz vein at a point 30 feet from the portal. This vein is 2 feet wide, strikes N. 35° E., and dips 76° SE. A sample selected from the dump assayed 3.77 percent copper and 0.60 ounce silver a ton.

The basalt flow is overlain by about 50 feet of banded gray-green sandy argillite overlain by about 150 feet of gray, gray-green, and red-purple coarse-grained sandstone and quartzite intermixed with argillite. Above this are red-purple cross-bedded coarse-grained sandstone, quartzite, and argillite. The strata above the flow are believed to represent the Shepard and lower part of the Kintla units of the Missoula Group.

Vein material at the Independence mine is estimated to contain 3 to 3½ percent copper. Selected specimens of ore have assayed 32 percent copper, but these high-grade specimens are not representative samples. Ore reserves would be difficult to determine without additional development work. A sample selected from a 5-ton dump at the portal of No. 1 adit on the Independence claim assayed 9.80 percent copper, 0.005 ounce gold, and 0.70 ounce silver a ton.

BLUE BIRD

The Blue Bird prospect is at the head of Bluebird Basin in the Whitefish Mountains of northeastern Lincoln County. The prospect is developed by a 25 by 4 by 4½-foot discovery pit, and a 102-foot adit (now caved). In July 1907, the Blue Bird Lode (MS 8502), consisting of 19.38 acres, was surveyed for patent (Fig. 40). The property at that date was owned by C. T. Young.

A 4-foot massive white quartz vein containing chalcopyrite, sparse chalcocite, and pyrite strikes N. 20° to 30° W. and dips 85° NE. The vein is in the Purcell Lava, which here strikes about N. 10° W. and dips 20° SW. A barren quartz vein in Piegan argillite below the base of the flow is about 125 feet to the northeast. A covered fault striking about N. 40° W. between the veins truncates the volcanic rocks. The northeast fault block moved about 150 feet northwest relative to the southwest block, bringing the lower section of the flow in fault contact with gray-green thin-bedded argillite (Snowslip Formation).

Selected specimens from the Blue Bird prospect assayed 2.36 percent copper, 0.002 ounce gold, and 0.20 ounce silver a ton.

Two vertical quartz veins striking N. 25° W. were observed in the Purcell Lava a quarter of a mile to the south. A mile or more to the south, some barite float was observed on the east side of the divide.

Another patented claim (MS 4421), in the Green Mountain area, was not visited, and no history of this property is available.

SWANSEA ROSA

The Swansea Rosa Lode claim (MS 8503) abuts the Blue Bird Lode in a saddle southeast of Green Mountain (Fig. 40). The claim, owned by Sidney Butler, was surveyed for patent in 1907.

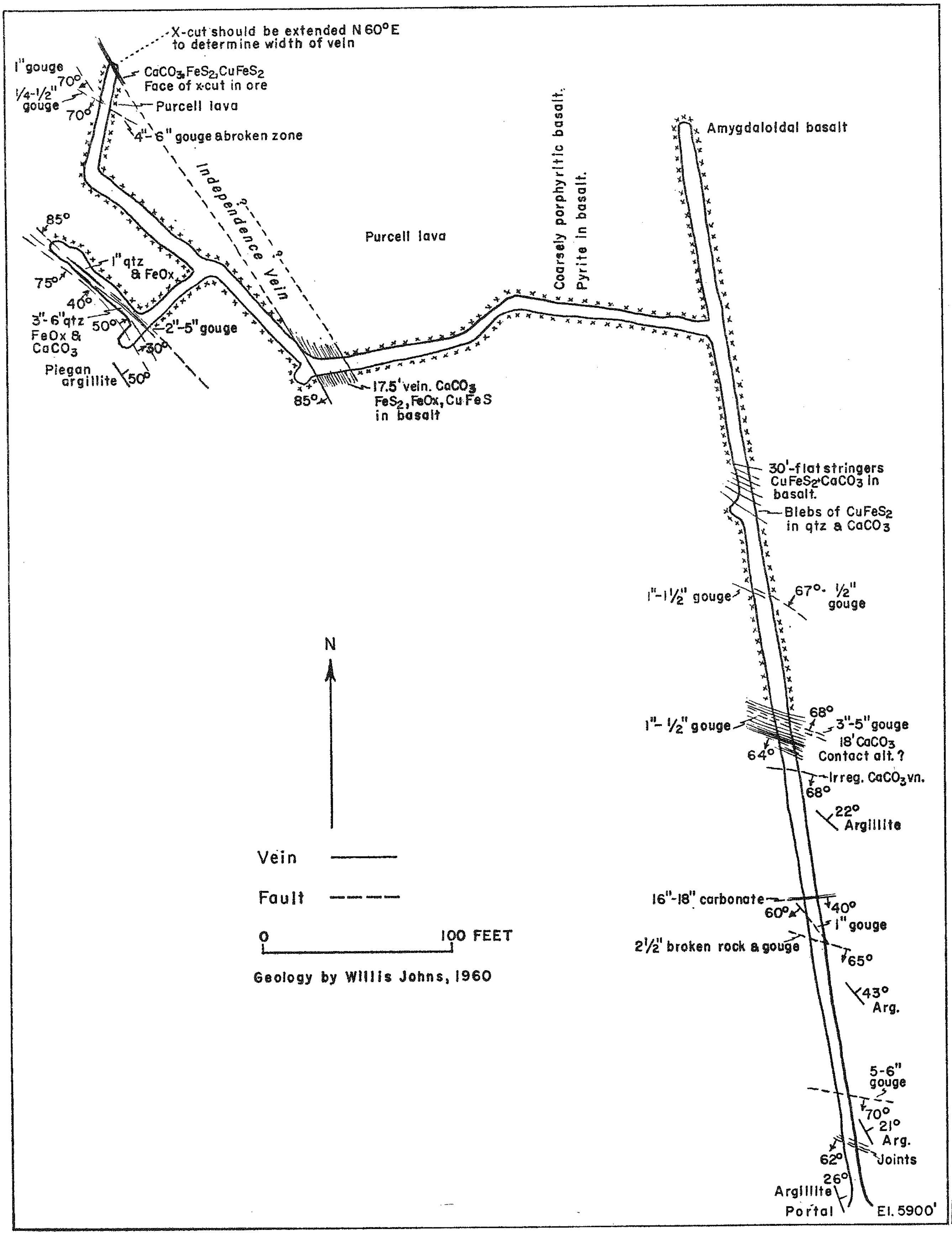


Figure 39.—Geologic map of lower adit (No. 3), Independence mine, Eureka district.

A 3- to 4-foot quartz vein follows the contact between Purcell Lava and overlying sedimentary rock for about 100 feet and is readily visible from U. S. Forest Service Trail No. 88, about a quarter of a mile to the east. Vein material includes barite, chalcopyrite, some tenorite, malachite, and pyrite in quartz gangue. Brecciated volcanic rocks have been invaded by quartz, barite, and copper and iron sulfides. The Purcell Lava in this area strikes about N. 10° W. and dips 20° SW.

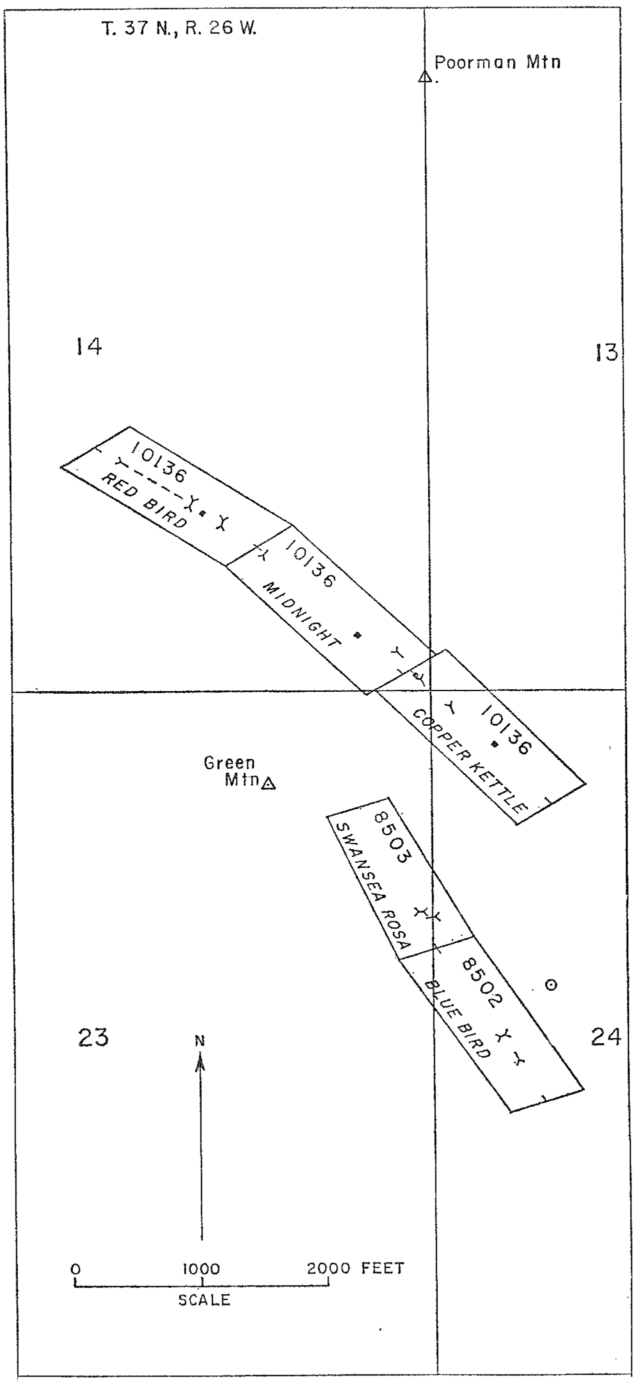


Figure 40.—Claim map of Blue Bird Lode (8502), Swansea Rosa Lode (8503), and Peterson property (10136), Eureka district.

Development work at the property consists of several shallow pits. In a park below the upper workings, a collapsed cabin and a caved 38-foot adit were observed.

A grab sample of barite-bearing vein material assayed 1.05 percent copper and 0.10 ounce silver a ton. Another assayed 1.74 percent copper and 0.40 ounce silver a ton.

PETERSON

The Peterson property (Twin Peaks Mining Company) is near the head of Blacktail Creek in the Whitefish Mountains of northeastern Lincoln County. The prospect was located about 1900 by Gust Peterson, who staked five claims on copper showings in the Purcell Lava, which crops out extensively on the west flank of a north-trending divide between Ksanka and Poorman Mountains. Three claims, Red Bird, Midnight, and Copper Kettle (MS 10136) (Fig. 40), were surveyed for patent in September 1917. It is developed by lower, middle, and upper adits, and two cuts and a shaft on the Red Bird (?) claim, two tunnels (caved) and a shaft on the Midnight claim, and two tunnels (caved) and a shaft (caved) on the Copper Kettle claim. At the base of a 30-foot shaft, Mr. Peterson encountered a 4-foot copper vein. In 1929, Howard and Herbert Poston of Kalispell formed the Twin Peaks Mining Company to develop the property. A 220-foot upper adit was driven to intersect the vein near the base of the shaft. The vein assayed 2 percent copper, 3 ounces silver, and a trace of gold a ton. In 1940, Hugh, Ross, and Warren Kirkpatrick did additional development work at the property.

At the time of examination (1960) the upper and lower adits on the Red Bird (?) were caved, and the middle adit seemed too dangerous to enter; consequently, no underground observations were possible in most of the underground workings. All information was obtained from observation of dump material and estimates of adit lengths.

Dump rock from the short upper adit contains disseminated chalcopyrite and malachite associated with quartz veinlets in Purcell country rock. The center tunnel, which is believed to be 300 to 400 feet long, has a 25-foot vertical shaft at the portal. The adit is in Purcell Lava, and the dump rock is entirely flow material containing some chalcopyrite in quartz associated with barite and calcite. The lower tunnel is estimated to be about 300 feet long. The dump rock contains some chalcopyrite, malachite, hematite, barite, and calcite as disseminations and veinlets in Purcell country rock. Two pits and a 15-foot tunnel were noted in this vicinity.

Selected specimens from the upper adit assayed 2.53 percent copper and 0.20 ounce silver a ton. Selected specimens of ore from the dump assayed 2.67 percent copper and 0.05 ounce silver a ton. There has been no production from this property, which had evidently been idle for 15 or 20 years.

TETRAULT

The Tetrault property is on the west slope of Poorman Mountain at the base of a steep cliff in Purcell Lava. U. L. Poston of Kalispell reported that a 2-foot vein of good-grade massive chalcopyrite is exposed at the portal of the adit, which was extended for 25 feet into the cliff. The prospect is difficult to reach and was not visited.

JAGER

The F. W. Jager prospect is in the Whitefish Range on the north side of Deep Creek, approximately 300 feet from the Deep Creek road in northeastern Lincoln County. The property is being developed by Fritz W. Jager of Fortine, Montana.

Six claims were located by Mr. Jager in 1929, on a 6- to 8-inch silver-bearing galena-chlorite vein, which strikes N. 72° E. and dips 72° S. Mr. Jager reported that samples from the outcrop assay 55 percent lead and 20 ounces silver a ton, and that material from the vein at the base of his discovery shaft adjacent to the outcrop assayed 37 percent lead and 13 ounces silver a ton. The upper tunnel and pit are in a metadiorite sill, which dips eastward. Bedding of sedimentary rocks in the area strikes N. 45° to 50° W. and dips 20° to 30° NE.

The prospect is developed by a discovery pit, a 70-foot adit intersecting the argentiferous galena vein at shallow depth, and a 476-foot lower adit being driven to intersect the vein at tunnel elevation. In the adit, a 4-foot calcite-siderite-quartz vein 87 feet from the portal strikes N. 70° W. and dips 80° SW. Some iron oxides and small amounts of pyrolusite are associated with the vein material. A 4-foot channel sample across the vein assayed 0.69 percent manganese. The analyst reported no gold or silver. Parallel faults marked by 2 to 3 inches of gouge and breccia delineate the walls of the vein. The next 389 feet of adit is in barren gray and gray-green siliceous to slightly calcareous argillite of the Piegan (?) Group, which strikes N. 30° to 40° W. and dips 19° to 38° NE. Several small northwest-striking bedding faults were mapped (Fig. 41).

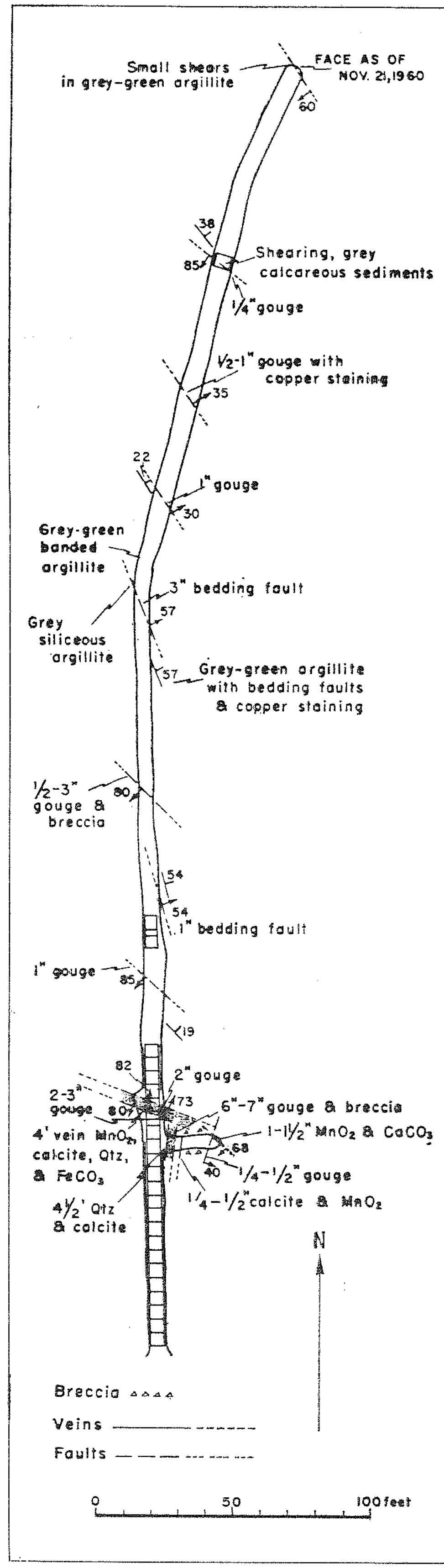


Figure 41.—Geologic map of lower adit, Jager prospect, Eureka district.

OTHER PROSPECTS AND VEINS

A prospect about a quarter of a mile below the Peterson prospect on Blacktail Creek has been tested by two pits, which show quartz in the Purcell Lava. Other quartz veins were observed on Blacktail Creek approximately half a mile below the Peterson property.

A 2-foot quartz-barite vein was mapped on the northeast slope of Green Mountain above U. S. Forest Service Trail 88.

On the slopes of Diamond Peak, about a mile east of Upper Whitefish Lake, small prospect pits were opened along a quartz vein, which 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 sheeted zone was not sampled.

STAR MEADOW DISTRICT

WEST VIRGINIA

The West Virginia was the first property discovered in the Star Meadow District, and the first producer of a small shipment of high-grade ore, which was packed out by horses. The property is on the west side of Sullivan Creek, 2 miles south of Star Meadow Guard Station and near the top of a small ridge separating Sullivan Creek and Griffin Creek (Fig. 42). It was discovered by John Sullivan prior to 1900. According to Art Stahl of Cranbrook, British Columbia, the property was first worked by John and Mike Sullivan and Bill Doyle, and financing was supplied by Charles Conrad of Kalispell. The near-vertical ore body terminated a short distance underground against a flat-dipping northeast-striking fault. According to Art Stahl, total production was 60 tons of ore.

Two veins exposed on the surface are developed by two shafts, an adit, a cut, and some trenching. The veins, about 65 feet apart, are near-parallel veins or one may be the displaced segment of the other. The West Virginia vein strikes N. 65° to 75° E. and dips 75° to 81° SE. This vein is developed by a shaft from which ore was stoped and by a 210-foot adit. Some trenching northeast and southwest of the shaft has exposed the vein for short distances. Surface exposures of the vein range from 4 to 13 inches in width, but the stoped area is as much as 4 feet wide. The other vein strikes N. 70° to 80° E., is vertical, and is developed by an 8- or 10-foot shaft and a 4 by 6-foot cut. This vein is 12 inches wide.

Vein minerals identified from samples in a small stockpile were chalcopyrite, some azurite, and a few flecks of bornite in hematite-stained quartz-siderite gangue. A small pillar of low-grade ore, left on the north side of the West Virginia shaft near the surface, contained small amounts of chalcocite-bornite intergrowths in quartz. Portions of the quartz vein have been leached of sulfides, leaving masses of reddish iron oxides. The ore body at the West Virginia may have been formed by secondary enrichment through conversion of primary copper sulfides to chalcocite. An adit crosscut intersects the vein at the base of the shaft. At this location a flat fault, striking N. 35° E. and dipping 5° NW, shifts the vein about 150 feet northeast. The fault selvage is ¼ to ⅜ inch wide. The flat-lying upper plate moved northeast and down, relative to the lower plate. The adit continuation along the normal fault to the lower vein segment was accessible but dangerous.

The ore shoot was localized above the flat fault, and bornite was reported as the main copper mineral. Moderate quantities of chalcopyrite were observed in samples from a small stockpile.

FOOLSBERG

The Foolsberg copper property is ½ mile south of the West Virginia at the head of Sullivan Creek. It is owned by Bill and Jess Stubs of Kalispell. The property was first developed in 1920, and the Foolsberg claim was patented in 1958 (MS 10824). The property has been inactive for some time.

Development consists of a 240-foot lower adit and a 300-foot upper adit; both adits are on the vein (Fig. 43). The difference in altitude between the two adits is 86 feet. The adits are on a fissure-filled chalcopyrite-bearing quartz vein, 16 to 54 inches wide, which strikes N. 80° W. and dips 80° SW.

The principal vein mineral in the upper adit is chalcopyrite, accompanied by tenorite, azurite, and malachite in quartz, siderite, and calcite gangue. An ore shoot, ranging in width from 16 to 30+ inches, is estimated to be 125 to 140 feet long. The country rock is green and gray-green banded argillite of the Piegan Group (p€pi₃), which strikes N. 85° W. and dips 15° SW. At a distance of about 190 feet from the portal of the upper tunnel, a vertical fault zone 2 to 6 inches wide strikes N. 55° E. This fault displaces both the vein and another fault striking N. 70° W. and dipping 56° SW. Gouge along this fault is 1 to 1½ inches wide and contains brecciated fragments, but its relationship to the vein is not clear. The drift follows the larger northeast-striking fault in a southwest direction for 60 feet. The displaced segment of the vein was not found. Vein bending

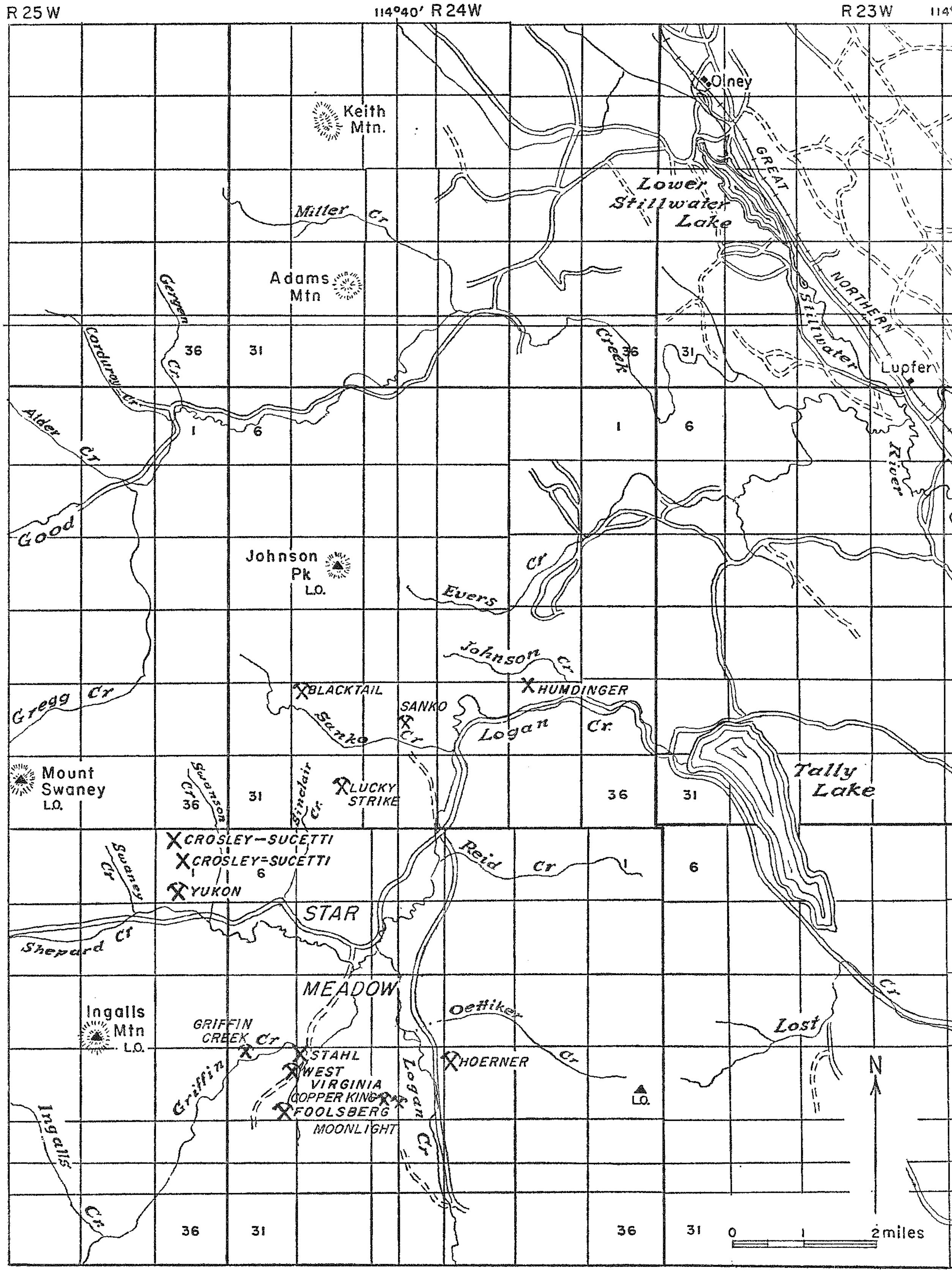


Figure 42.—Map showing locations of properties in Star Meadow district, Salish Mountains, Flathead County.

adjacent to the northeast-striking fault indicates that the displaced vein segment probably moved northeast; the drift should have followed the fault in a northeast direction to intersect the ore shoot. A chip sample across the 38-inch width of the ore shoot in the upper adit assayed 4.87 percent copper, 0.80 ounce silver, and 0.05 ounce gold a ton.

The lower tunnel intersects the vein near creek level and follows it N. 80° W. The vein ranges from 14 to 32 inches in width. Only sparse chalcopyrite was noted in the gangue of quartz and siderite. The lower adit should be advanced an additional 50 to 75 feet, as the ore body may have a westerly rake. A grab sample from the dump of the lower adit assayed 2.98 percent copper, 0.60 ounce silver, and 0.15 ounce gold a ton.

Harold Stee, exploration geologist, was reported by the late Harold Luke to have examined the property around 1931 and recommended that the lower adit be advanced westward an additional 50 to 100 feet.

BLACKTAIL

The Blacktail prospect is on a small tributary of Sanko Creek in the north part of the Star Meadow district. It was discovered by Frank Lykin of Pleasant Valley after the 1936 Sanko Creek fire burned the vegetation that had covered the vein. The original Blacktail claim was staked in 1938, and in 1940 Lykin brought in two partners, Helmer Hofland and Andrew Bruhjell. A short shaft was sunk in the creek and an adit was driven 10 feet on the vein. The claim was allowed to lapse, and Clarence Burke relocated the ground in 1945. In May and June of 1961, Marion Fishel of Kalispell relocated the Blacktail and two additional claims. Total production from the property has amounted to 36 tons of ore; the first 8-ton hand-sorted shipment assayed 13.65 percent copper.

In 1961, the vein was exposed for a distance of 200 feet by eight pits and a 20-foot adit. Subsequently the adit was extended along the vein, and bulldozing exposed the vein, containing chalcopyrite and quartz, for a distance of 300 feet.

The Blacktail vein strikes eastward and dips 81° S.; its width ranges from 2 to 10 inches, and is 9 inches near the portal of the adit (Fig. 44). Moderate to abundant chalcopyrite, sparse galena and cerussite, and pyrite in quartz gangue make up the mineral assemblage. Oxidation extends 4 to 6 feet below the surface; within the oxidized zone sparse to moderate amounts of chrysocolla, malachite, and azurite were identified.

On the north (footwall) side, small northeast-trending joints or small shears filled with iron oxide are truncated by the vein. At the face of the adit, a small northwest-striking and southwest-dipping high-angle fault displaces the vein a short distance. Country rock is thin- to medium-bedded light-gray and yellow-gray argillite and calcareous argillite (p€pi₁) striking N. 40° W. and dipping 10° NE.

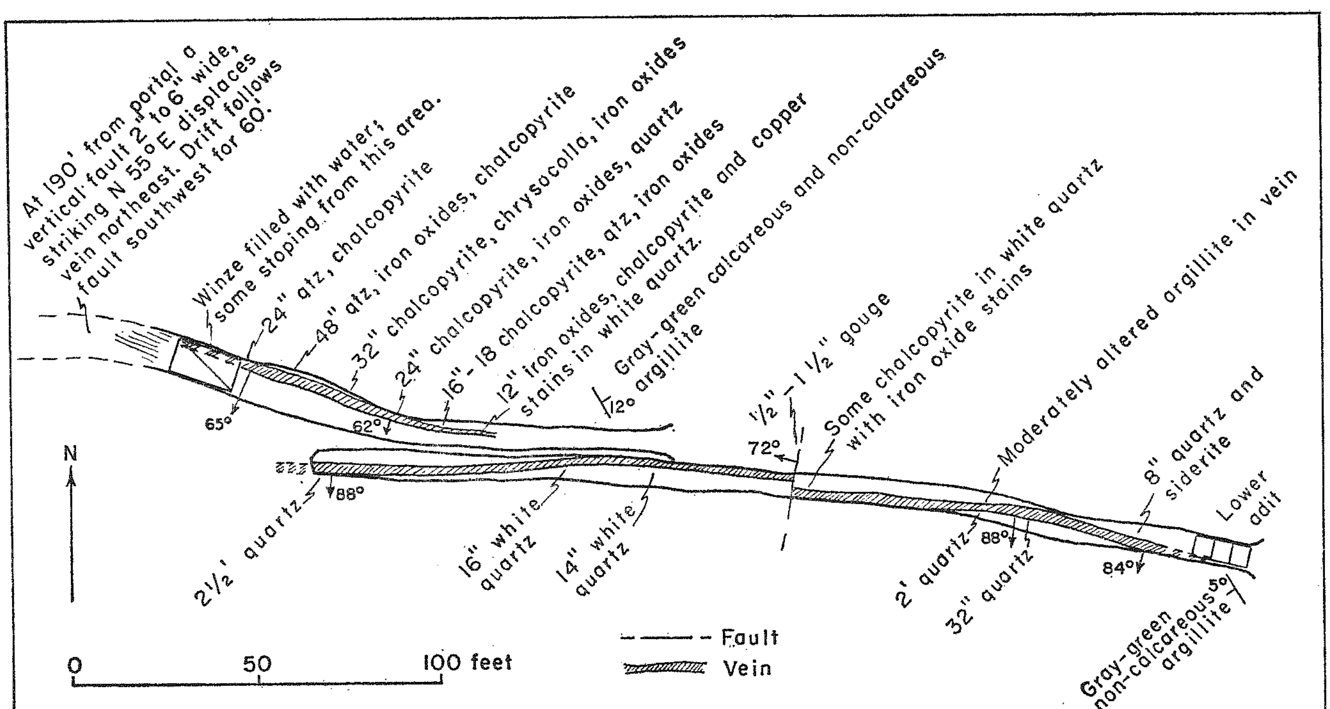


Figure 43.—Geologic map of lower and upper adits, Foolsberg mine, Star Meadow district.

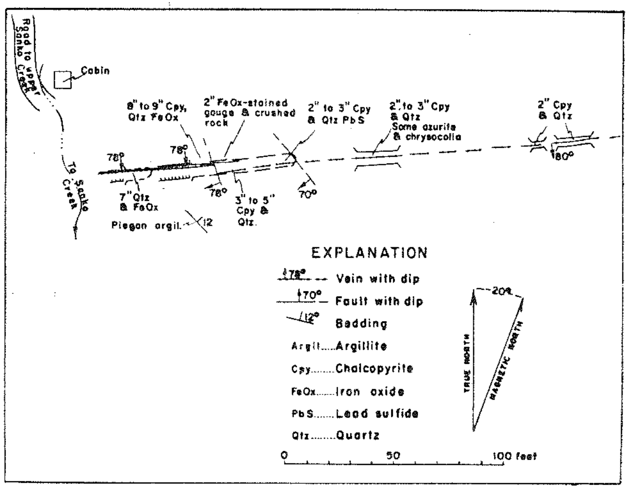


Figure 44.—Surface plan of Blacktail mine, Star Meadow district.

A channel sample across 10 inches of vein at the portal of the adit assayed 9.64 percent copper, 2.80 ounces silver, and 0.04 ounce gold a ton. Selected specimens of chalcopyrite assayed by Marion Fishel contained as much as 18 percent copper. The writer selected specimens from a 2-ton stockpile of ore, which assayed 28.40 percent copper, a trace of gold, and 4.70 ounces silver a ton.

HUMDINGER

The Humdinger unpatented claim, 2 miles west of Tally Lake between Logan Creek and Johnson Creek, was staked by Fred, Leroy, Ernie, and Harold Luke in 1934. The property is reached by a short access road from the Tally Lake-Logan Creek-Star Meadow road. It is about 25 airline miles northwest of Kalispell. Country rock is gray-green banded argillite (P_1) of the Piegan Group. There has been no production from the prospect.

Development consists of two pits exposing two closely spaced veins and a 100-foot adit crosscut (now caved) intersecting the veins at a shallow depth. The development was done during the mid-thirties. Dump rock at the adit contains sparse chalcopyrite and tenorite in brecciated quartz-siderite-talc gangue. Some native copper was found by the Luke brothers in one of the pits on the outcrop. Two pits approximately 40 to 50 feet (vertically) above the portal of the adit exposed two separate veins. The vein in the upper pit (No. 1) strikes eastward and dips 65° N. The quartz-siderite-calcite vein is 14 inches wide and contains iron oxides. Pit 2 is on a 40-inch vein, which strikes N. 75° E. and dips 55° N. The vein contains tenorite, malachite, and sparse native copper in quartz-siderite-calcite gangue, and a white to reddish heavy nonmetallic mineral, probably barite (and some celestite?).

YUKON

The Yukon property is about a mile west of the Star Meadow Guard Station on Sheppard Creek and one-eighth mile north of the Star Meadow road. The one unpatented claim was located by Fred and Ernie Luke in 1929. Development includes a 257-foot adit crosscut to the vein, approximately 70 feet of drifting on the vein, a 10 by 12 by 8-foot pit on the outcrop, and a 20-foot shaft a short distance east of the pit. In recent years Harold, Leroy, and Carl Luke have done a small amount of underground development on the property.

At the portal of the adit a 12- to 16-inch vein striking eastward contains chalcopyrite, chrysocolla, and tenorite, in a quartz-siderite matrix. Some small kaolinized argillite horses of sedimentary rock were noted within the structure. Chalcopyrite, tenorite, malachite, and chrysocolla were found on the dump.

A 30- to 42-inch vein of quartz and siderite intersected by the adit contains sparse chalcopyrite, tenorite, chrysocolla, manganese dendrites, and iron oxides. The vein is vertical and strikes east-west. The vein exposed in the pit is 14 to 22 inches wide. Sparse to moderate amounts of chalcopyrite and tenorite are contained in quartz-siderite gangue. About 50 feet east of the pit a 20-foot shaft (now inaccessible) was sunk on the easterly extension of the vein. Here the vein is 14 to 18 inches wide and is reported to widen at depth.

The workings are in gray-green banded Piegan sedimentary rocks, which strike N. 10° W. and dip 12° SW. The dense country rock is stained with manganese oxide.

Some ore from the Yukon (about 15 to 20 tons) was included in a 100-ton shipment from the Foolsberg mine in the late thirties. The ore is reported to have averaged $27 a ton in copper. A sample from the dump at the adit assayed 3.37 percent copper, 0.15 ounce silver, and 0.002 ounce gold a ton.

COPPER KING

The Copper King prospect is on a ridge top, about a mile east of the West Virginia, in the Star Meadow district. The property was located by Lee Bigland in 1946.

A 12-inch vertical east-striking quartz vein containing sparse chalcopyrite is developed by two shallow pits. The pits are on the west limb of an anticline in thin- and medium-bedded ripple-marked medium-gray calcareous argillite and limestone. A chip sample across the vein assayed a trace of gold and 0.20 ounce silver a ton.

MOONLIGHT

The Moonlight claim, half a mile east of the Copper King on the west side of Logan Creek about a mile south of the mouth of Oettiker Creek, was located by Harold and Carl Luke of Kalispell. Development consists of several shallow pits on quartz veins. There has been no production from the prospect.

Three parallel closely spaced vertical veins strike eastward. A fourth parallel quartz vein lies about 300 feet south of the others. The three parallel veins are 8, 12, and 18 inches wide and contain small amounts of chalcopyrite, malachite, azurite, and chrysocolla. Masses of red pulverulent iron oxides are associated with the secondary copper minerals.

The prospect is on the east flank but near the crest of a gently dipping anticline in thin-bedded medium- and light-gray calcareous argillite that weathers gray and yellow.

GRIFFIN CREEK

The Griffin Creek prospect is on the northwest side of Griffin Creek 2 miles south of Star Meadow Guard Station. The property is developed by a 20-foot trench and a 12 by 4 by 6-foot pit. Country rock is gray-green argillite (p€pi₁) and very pale yellow-gray and yellowish-white siliceous and calcareous argillite and dolomitic limestone. The sedimentary rocks strike N. 30° W. and dip 15° SW.

No history of the prospect is available, but the work seems to have been done in the 1920's or 1930's.

An 8- to 9-inch vuggy quartz vein strikes eastward and is vertical. Large rhombohedrons of calcite or ferruginous carbonate are contained in rock on the dump. In the vein at the upper pit, sparse chalcopyrite, tenorite, calcite, and hematite were observed.

A selected sample from the dump at the upper pit assayed 1.38 percent copper, a trace of gold, and 0.30 ounce silver a ton.

SANKO

The Sanko vein, on the north side of Sanko Creek, about 1½ miles west of the Humdinger claim and a few feet north of the Sanko Creek road, was discovered by Fred Sanko prior to the 1930's. A 4- to 6-inch vertical quartz vein containing medium-sized quartz crystals and iron oxides strikes eastward and is developed by a 4 by 4-foot pit. The country rock is thin- and medium-bedded yellow-brown, yellow-gray, and light-gray argillite, which strikes northward and dips about 12° E. These beds are in the Piegan Group (p€pi₁).

LUCKY STRIKE

The Lucky Strike is north of Sheppard Creek in the Star Meadow district, about 1½ miles southeast of the Blacktail property. It was discovered by Fred and Ernie Luke between 1915 and 1918.

An 8- to 18-inch quartz vein containing chrysocolla strikes eastward. The country rock is yellow, yellow-green, and gray-green limestone of the Piegan Group, which strikes N. 20° W. and dips 8° NE. The prospect is being developed by Leroy, Carl, and Bud Luke of Kalispell.

BLUE GROUSE

The Blue Grouse prospect is adjacent to and on the east side of the North Fork of Herrig Creek, about 3½ miles north of Little Bitterroot Lake. The property includes four claims staked by Glen, Lloyd, and Manuel Bauska and Neil Graham. These unpatented claims were relocated in September 1960 and in July 1961.

Development work includes a 27-foot adit driven sometime in the 1930's, a 10 by 6-foot pit, and a 4 by 4-foot pit. At the main workings, three quartz veins, 20, 24, and 36 inches wide, crop out adjacent to a trail bordering the North Fork of Herrig Creek on the east side. The two smaller veins are developed by the adit and pits. The +36-inch vein crops out about 100 feet south of the main workings, and has not been developed. One-fourth to one-half mile north of the main workings and adjacent to metadiorite dikes, three quartz veins 3 to 6 inches wide exposed in several small pits strike eastward and northwest, and dip steeply to the south and southwest.

At the main workings (Fig. 45) the quartz veins are barren except for magnetite, sericite, chlorite, and some iron oxides in vugs. Glen Bauska reported that some selected vuggy material assayed 3 ounces silver a ton and contained a small amount of gold. The very sparse silver in the vein seems to be spotty and associated with vugs. The country rock is banded blue-gray argillite, containing biotite and magnetite, and very light gray fine-grained magnetite-bearing quarzite and argillaceous quartzite of the basal part of the Ravalli Group.

An anticlinal axis is about one-tenth mile west of the quartz veins. The trace of the axis trends slightly west of north, and the veins are thought to occupy tension faults related to folding stresses and dike intrusion.

In the general area of the Blue Grouse prospects, two high-grade specimens of quartz containing native gold have been found. The first specimen was reported found in 1914 by Charlie Ayers, U. S. Forest Service packer, near a spring a few hundred feet west of the Blue Grouse workings. The angular piece of quartz float contained native gold and iron oxides. The second specimen was found by Glen Bauska in 1929 near a spring about a quarter of a mile southwest of Pleasant Valley Mountain. This specimen, containing wire gold in vuggy quartz, was assayed by the Colorado School of Mines and reported to contain $17,500 a ton in gold. Bauska believed that this specimen may have been packed to the vicinity of the spring.

According to rumor, a Mr. Foster, who was a tunnel watchman at the Haskill Pass tunnel of the Great Northern Railway before the railroad was rerouted along the Kootenai River in 1904, found coarse native gold in quartz in the Haskill area, which is near the Blue Grouse prospect. Several Marion residents at that time supposedly saw samples of Mr. Foster's ore. Mr. Foster is supposed to have excavated all the ore from this particular outcrop, but he did commence working in an adjacent area, which he thought might be as productive. From reported descriptions of the ore, Marion residents at the time believed that the deposit was a lens in a quartz vein north of Haskill Pass.

HORSE HILL

Just northwest of Horse Hill Lookout 5½ miles north of Island Lake a prospect has been explored by a short adit and winze. A 14-inch vein is exposed by a 50-foot adit trending S. 70° E. A few small quartz stringers parallel the larger vein. A winze at the face of the adit is now filled with water. From visual observation, dump and vein material seem barren. A sample of vein material assayed a trace of gold and 0.10 ounce silver a ton.

CROSLEY-SUCETTI

The Crosley and Sucetti prospects are ½ mile north of the Yukon property on a small drainage between Swanson Creek and Swaney Creek. Mr. Crosley of Star Meadow did the first work in the area prior to 1910. Mr. Sucetti did additional prospecting and development in the early 1920's. The prospects have been inactive for many years. Development work consists of a short discovery adit on a 4- to 6-inch quartz-siderite vein, and a 30-foot adit on a 12- to 16-inch quartz-siderite vein containing specular hematite. The specular hematite vein strikes N. 85° W. and dips 75° S. It contains some chlorite. The country rock is the Piegan Group (p€pi₁).

STAHL

Art Stahl reported that in 1904 he located and did development work on a property about a quarter of a mile north of the West Virginia mine on the east side of Griffin Creek. The workings

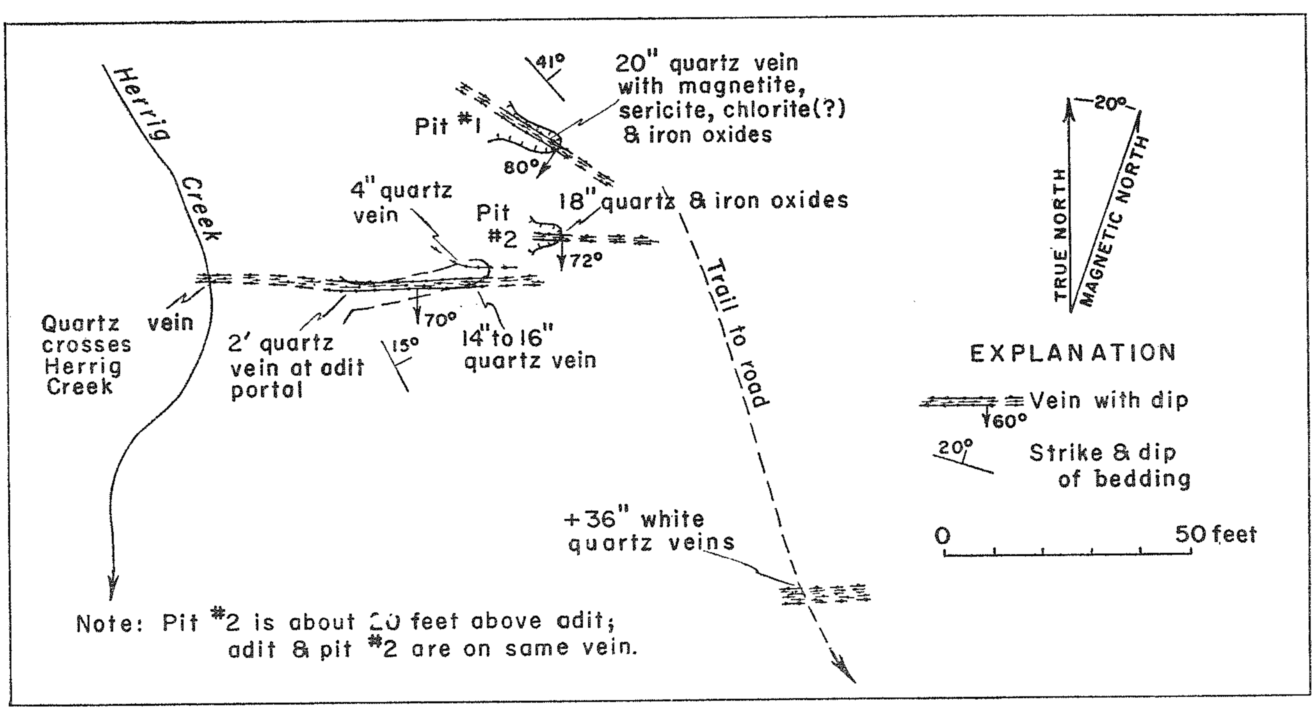


Figure 45.—Surface plan of Blue Grouse prospect, Star Meadow district.

were not visited, but from the description given, they may be on privately owned ground.

According to Stahl, a 6-inch to 3-foot mineralized zone was developed by a 60-foot adit. Samples from a few stringers 2 to 3 inches wide were reported to have assayed some copper and silver.

OTHER PROSPECTS AND VEINS

An abandoned prospect is several hundred feet east of the West Virginia property; development work amounts to a 150-foot (?) adit, now caved, that trends S. 50° E. The adit is believed to have been driven about 1930 or 1932 by Kalispell prospectors. Selected specimens from the dump contained sparse chalcopyrite and iron oxides in a quartz-siderite gangue and assayed 0.46 percent copper, 0.03 ounce gold, and 1.40 ounces silver a ton.

Considerable development has been done on a northeast-striking vein a quarter of a mile northeast of the West Virginia property. A vuggy quartz vein as much at 2 feet wide is vertical and strikes N. 65° to 70° E., about parallel with the West Virginia vein. It has been explored by an adit, a shaft, and several pits and trenches. The adit and shaft are now inaccessible. The vein quartz is stained with iron oxide, has rhombohedral cavities, and is barren of sulfide minerals and copper staining.

Two parallel quartz veins, approximately 600 and 1,000 feet south of the West Virginia property, strike N. 80° W. and dip 80° SW. The vein material is conspicuously stained with iron oxides. The veins are developed by shafts, which are 14 and 25 feet deep, and by several shallow pits. The veins range in width from 6 to 14 inches, are vuggy, and contain hematite and siderite.

A 4-inch vertical quartz vein striking eastward crops out along a Forest Service trail ¾ mile southwest of Johnson Peak. The barren quartz is stained with small amounts of iron oxides.

Carl Luke reported finding a vein of galena 3 inches wide adjacent to a Forest Service trail 3¾ miles north of Ashley Mountain. Luke also found galena float about 2 miles west of this location.

An 8 by 8 by 10-foot shaft exposes a vein 10 inches wide containing rusty to brown vuggy quartz. The vein is 1½ miles northeast of Lone Lake on Ashley Creek.

On the top of Boorman Peak an 8-inch vertical vein of vuggy quartz, hematite, and calcite is exposed in a shallow pit.

An adit on the north slope of Grubb Mountain is driven in a southerly direction on a quartz vein.

A small quartz vein is exposed along the north side of the road to Tepee Hill.

The Luke brothers have located the Peacock property ¾ mile northeast of the Yukon property. A selected sample from a zone of ⅜- to ½-inch veinlets assayed 32.4 percent copper, 72.7 ounces silver, and 0.30 ounce gold a ton.

Other diggings have been noted (personal communication, Harold Luke) along a Forest Service trail about a mile northwest of the Griffin Creek prospect and also on the east side of Ingalls Mountain.

About 1930, Mr. Rhodes, a rancher living in Lost Creek valley, northwest of Kalispell, reported discovering a lead-silver vein on an east-trending ridge north of Ashley Lake. Rhodes described the vein as being found at the base of an outcrop; specimens of the material assayed $96 a ton in lead and silver. The major value of the ore was reported to have been in silver. Rhodes spent the next several years trying to rediscover this vein. From information supplied by Glen Bauska, Rhodes seems to have found the vein at the head of the South Fork of Big Lost Creek. The writer spent a short time in this vicinity without finding ore. In this area a tight syncline trends about N. 20° W., and a parallel vein might follow the fold axis.

About 4 miles east of Boisvert's camp on McGregor Lake and 600 feet south of U. S. Highway 2, are gravels cemented by hematite and silica, which assay 1.80 percent manganese, a trace of gold, and 0.10 ounce silver a ton. These gravels have been uncovered by bulldozers working in a Highway Department gravel pit.

HOG HEAVEN DISTRICT

The following mining properties were described and mapped by W. D. Page.

FLATHEAD

The Flathead mine (Fig. 46), 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. Because of flooding and treacherous conditions, Page was unable to examine much of the workings. Ore deposits in this mine are 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. The main ore body rakes steeply south.

The primary minerals are sulfides; most abundant are pyrite, galena, and antimonial matildite, but some enargite and bornite are included. The gangue is barite, alunite, quartz, and clay. Rhodochrosite is reported to fill casts in wall rock. Shenon and Taylor (1936, p. 17) showed 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 sulfides . . . 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

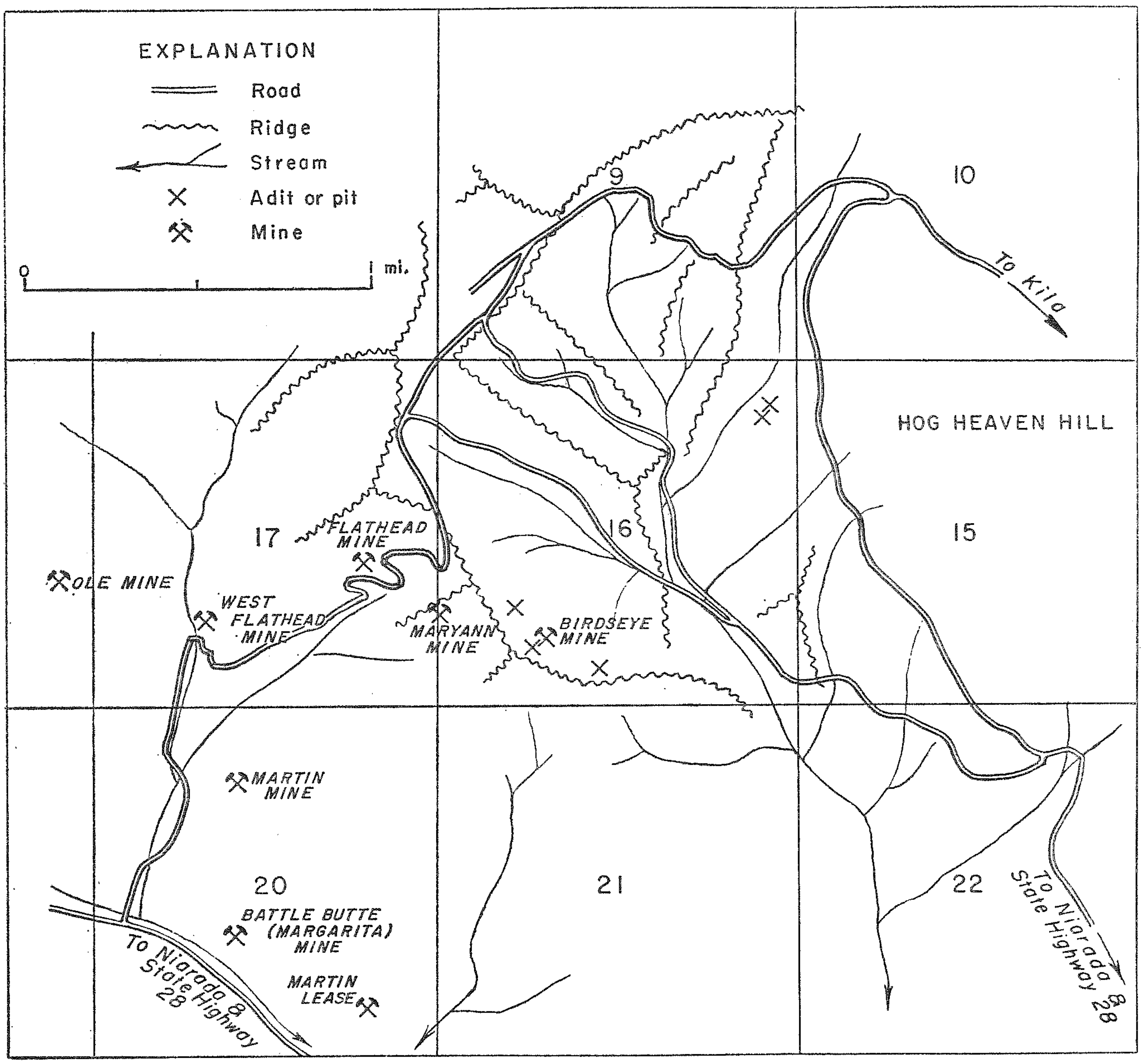


Figure 46.—Map showing locations of mining properties in the Hog Heaven district, Flathead County.

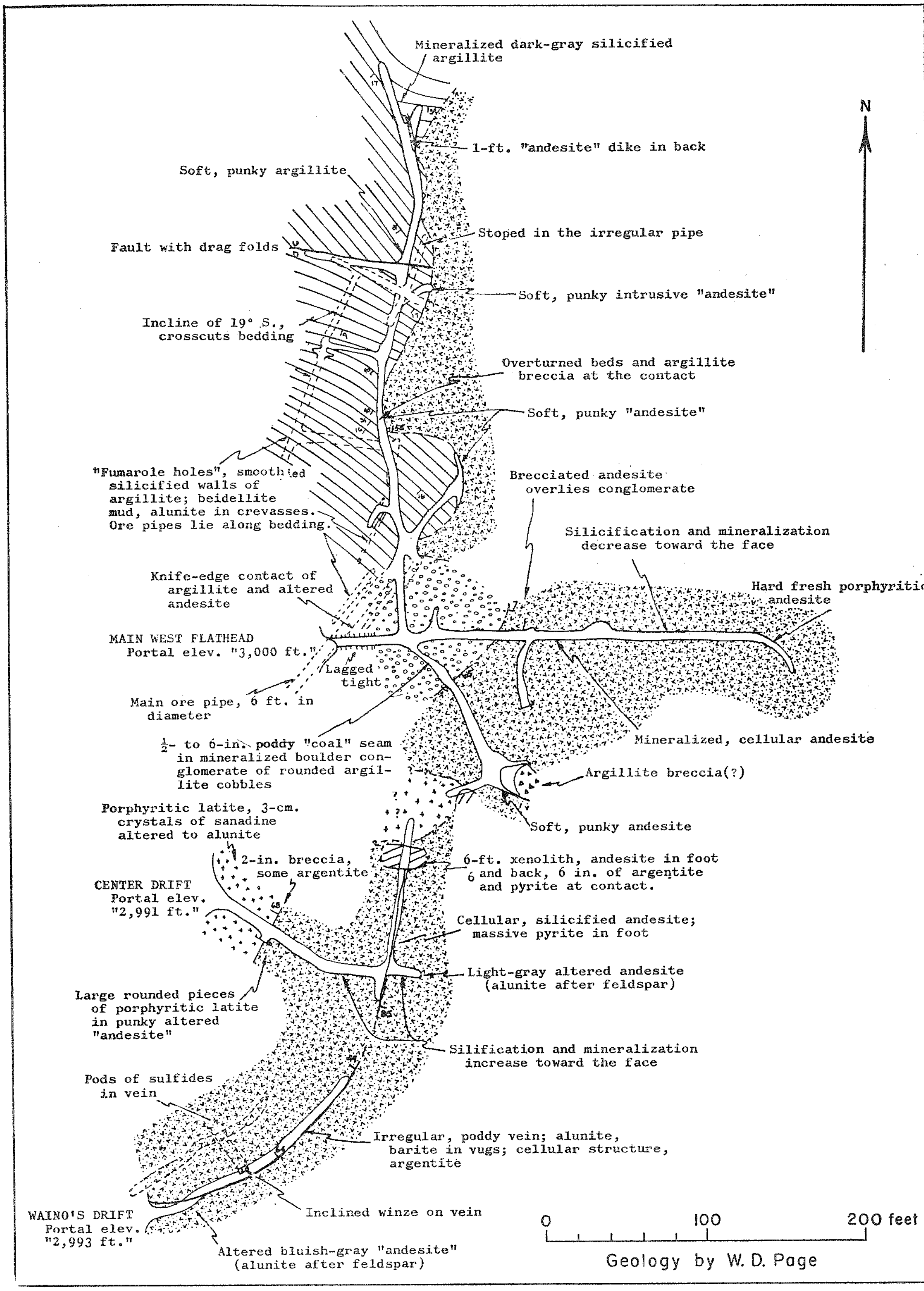


Figure 47.—Geologic map of West Flathead mine, Hog Heaven district.

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 and marcasite are the most common minerals in this zone, but covellite and chalcocite are 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 and sulfate of ferric iron, lead, and bismuth) and sparse amounts of anglesite, siderolite, melanterite, and malachite. 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 abundant 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

The West Flathead mine (Fig. 47) 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 mineral is argentite, which occurs in "beidellite mud". The clay-rich mud fills smooth, rounded tubes and solution holes in the argillite, which probably resulted from fumarole leaching and subsequent mineralization, hence the tubes are called "fumerole 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 along bedding planes, but tabular "fumerole 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 scarce in the igneous rocks, in striking contrast to the Flathead mine. Low-grade ore at the West Flathead, however, is most extensive in the igneous rocks; disseminated pyrite and other sulfide minerals are extensive in parts of the andesite. Mineralization is intense around joints and fractures, making small veins and pods where fractures intersect. Waino's drift follows one of these veins (Fig. 47). The vein is irregular and "poddy" and consists mainly of beidellite, beudantite, barite, alunite, and some argentite. Primary sulfides (pyrite, argentite, tetrahedrite, 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. Near the portal of the center drift, altered porphyritic latite has been intruded by porphyritic andesite. The latite is similar to that near the Flathead mine and is probably related to that body. The andesite is probably part of the 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 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.

Yellow granular material sampled in one of the fumarole holes in the West Flathead property was reported to assay 5.2 percent lead, 0.03 percent copper, 310 ounces silver, and 0.03 ounce gold a ton. Another sample streaked with black material assayed 7.1 percent lead, 0.16 percent copper, 451 ounces silver, and 0.03 ounce gold a ton.

OLE

The Ole mine consists of exploratory drifts and shafts (Fig. 48) in an altered porphyritic latite(?) plug that has intruded argillite of the Ravalli Group. Supergene argentite mineralization in the porphyritic latite has associations similar to those of the Flathead and West Flathead mines. Pyrite, barite, beudantite, and some alunite form veins and are disseminated near silicified cellular latite, but the argillite has been only slightly altered. It is silicified near 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.

Dan Grant of Kalispell obtained a lease on the Ole property in 1961 from the Northern Pacific Railway Company. In 1963 to 1964 Dan Grant, Darrel Clothier, and Herman Slama, of Kalispell, did considerable exploration work in the vicinity of the tunnels. They shipped 150 tons of ore containing 5 ounces silver a ton from a vertical face described below.

Considerable trenching and stripping have exposed more of the porphyritic latite intrusive body, which is more extensive than shown on geologic maps. It is irregular in surface plan and has an easterly or southeasterly rake.

Approximately 150 feet west of the Phillips adit portal and on the west side of a small hill, the contact between latite and sedimentary rock dips 20° W.; Ravalli argillite strikes northeast and dips

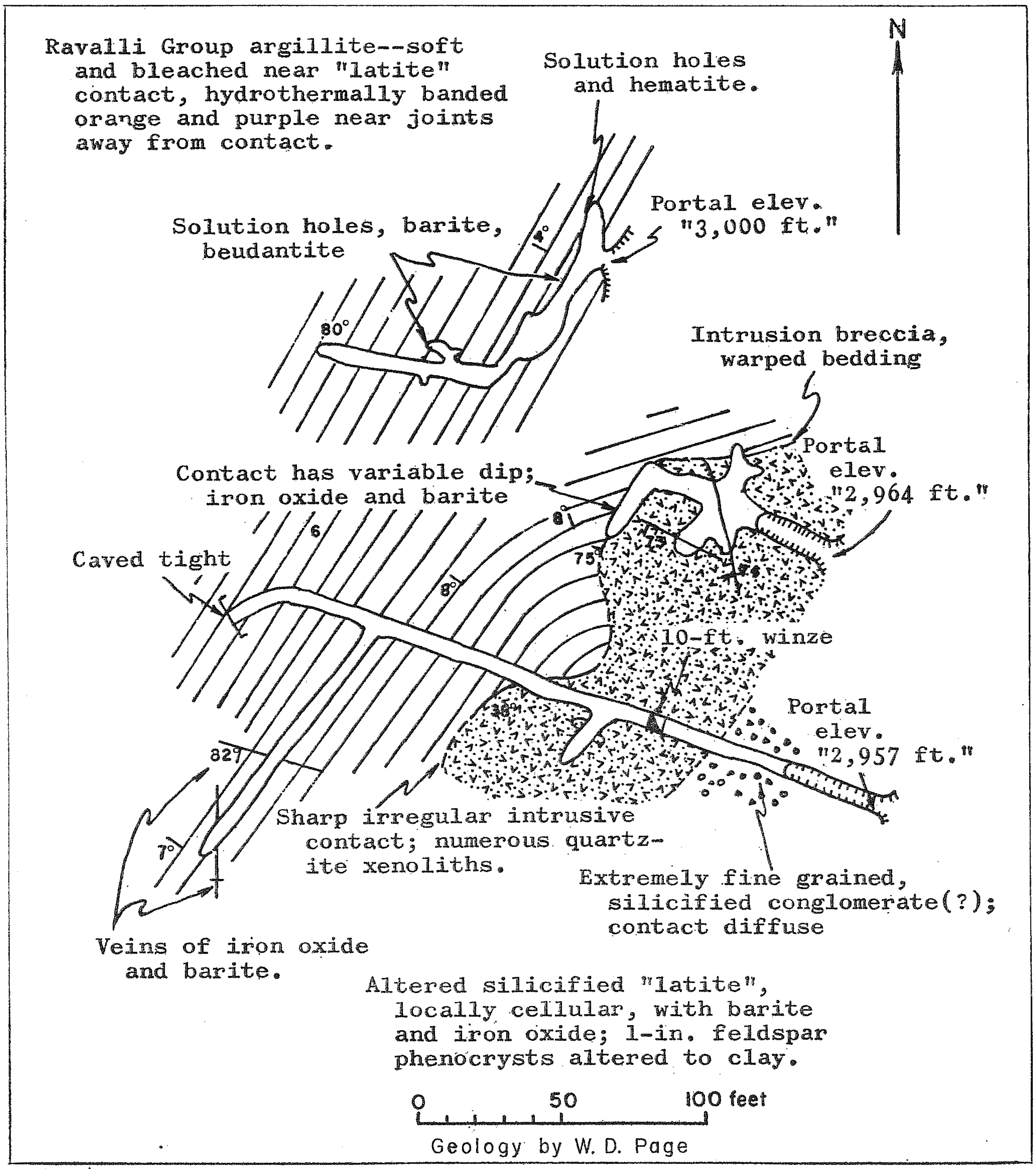


Figure 48.—Geologic map of Ole mine, Hog Heaven district.

at low angles northwest in the vicinity of a 20- to 25-foot vertical face exposed for 100 feet by bulldozing. Near the base of this face is a brecciated contact zone overlain by porphyritic latite. The contact zone for 1 to 2 feet above the argillite contains moderate to abundant amounts of barite and quartz and some pyrite; it is vuggy and stained with iron oxide, resembling a gossan. A zenolith of silicified Ravalli argillite in latite several feet above the contact has its rim replaced and cracks filled by barite. Barite veinlets in the latite are as much as an inch wide, strike north and east, and are reported to assay 15 ounces silver a ton. Some veinlets continue into Ravalli country rock; at the north end of the intrusive body, barite veinlets ⅛ to ¼ inch wide parallel bedding planes in Ravalli strata. Two nearly horizontal fumarole holes, about 1 foot in diameter, in Ravalli argillite at the portal of an adit near the northwest end of the intrusive body, contained material reported to assay 60 ounces silver a ton. The fumerole holes seem to have originated from the latite.

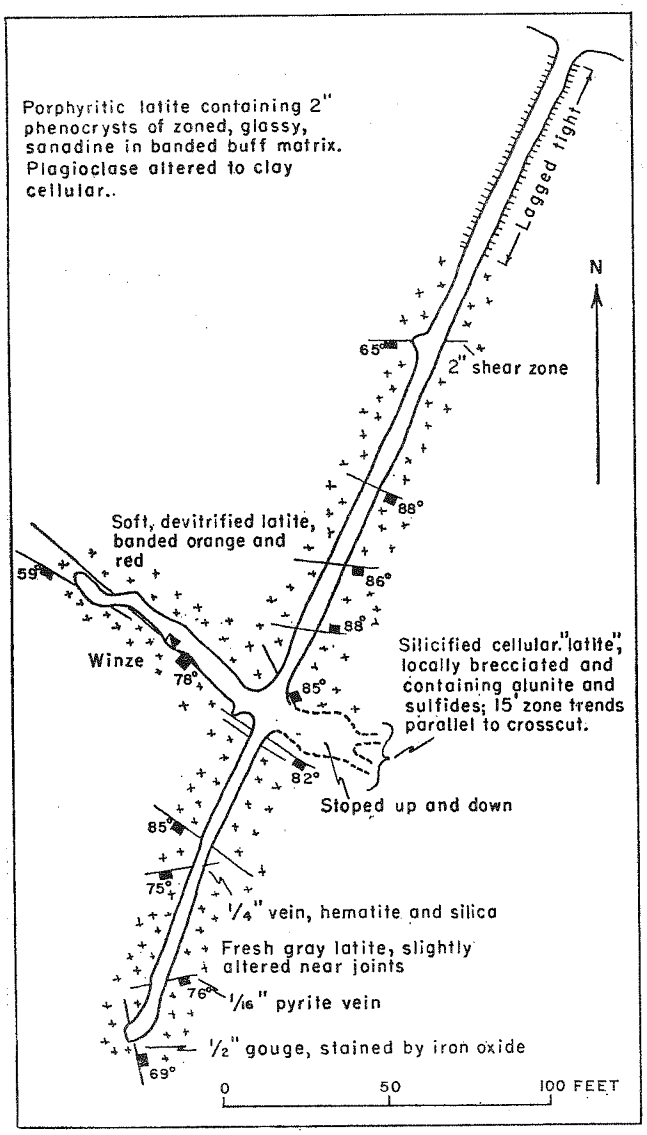


Figure 49.—Geologic map of Birdseye mine, Hog Heaven district (W. D. Page).

BIRDSEYE AND MARYANN

The workings of the Birdseye (Fig. 49) and Maryann mines are in porphyritic latite. These deposits are 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

The Martin mine (including the Battle Butte mine) (Fig. 50) 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 ore 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. The ore, 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, especially in the vicinity of the Flathead and Martin mines, two unexplored mineralized areas in the volcanic rocks probably warrant exploration. In an area 4 miles west of Battle Butte, nodules of silica and iron oxides containing beudantite are scattered on the surface. The nodules probably resulted from fumarole activity possibly related to a quartz latite intrusive body a mile to the north. The nodules assayed only 0.3 ounce silver a ton, but silver assays of surficial rock in the district are generally low.

In another area, just west of Hubbart Reservoir, limonite veins and nodules exposed in a recent dozer cut assayed 0.4 ounce silver a ton.

It has been reported that Paul Sperry discovered barite float along(?) the Schroder fault about 10 miles south of Castle Rock and north of the Flathead Indian Reservation boundary. As barite has not been found in place, the extent of mineralization is unknown.

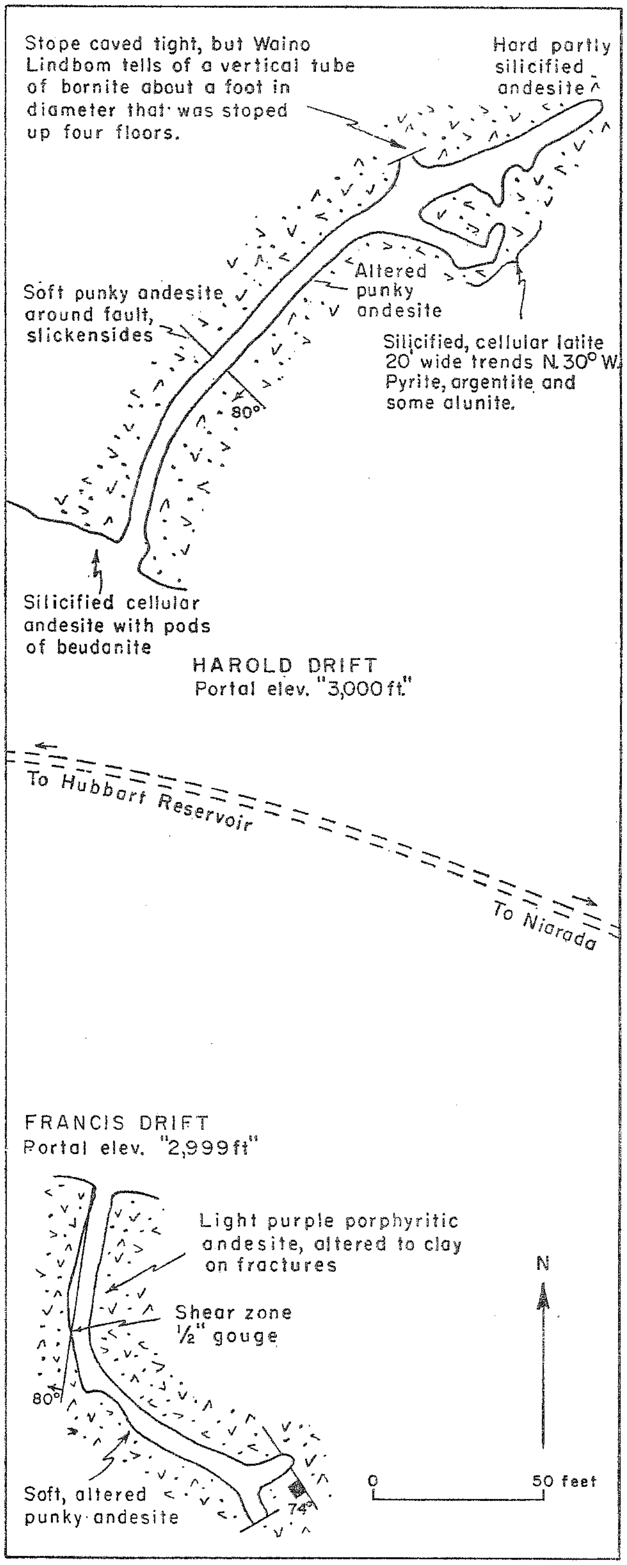


Figure 50.—Geologic map of west drifts, Martin mine, Hog Heaven district (W. D. Page).

KALISPELL AREA

WORT

The Wort prospect, formerly the Lupfer (Leupfer) property, is 7 miles northwest of Whitefish and about 150 feet south of the Great Northern Railway. It is on a ranch acquired by George S. Wort in 1948. Development work is believed to have been done between 1909 and 1912. In 1910 the property was being developed by the Lupfer Mining Company, who employed six men sinking a shaft (Walsh and Orem, 1910). The property was active until at least 1912.

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 by 10-foot shaft, 150 feet deep, now filled with water. From the base of the shaft a well-defined copper vein was followed for 150 feet. Country rock is argillite in the lower part of the Piegan, which strikes N. 25° W. and dips 36° E. According to the late 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.

MICHO

The Micho prospect is at the south end of the Whitefish Mountains on a southwest-flowing tributary of Haskill Creek. 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 ore minerals were noted on the dump, and it is thought that the excavations explored iron- and copper-stained beds of the Grinnell Formation.

SEEK

The Seek prospect is on the west flank of the Swan Range, a mile northeast of Lake Blaine. Development begun by Mr. Seek in 1922 includes a 12-foot cut and an 8-foot slightly inclined adit on a 2½-foot bed of white iron-stained quartzite in grayish-red argillitic siltstone of the Ravalli Group. The quartzite was not sampled.

OTHER PROSPECTS AND VEINS

Along the Truman Creek road 2½ miles northwest of Blacktail Mountain, a 6-inch nearly vertical quartz fissure vein containing iron oxides strikes N. 80° 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.

About 5 miles east of Smith Lake an adit 150 feet long, bearing S. 74° W., was driven in middle Piegan magnesian limestone (Siyeh Formation), which strikes N. 60° W. and dips 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 about 10 miles northwest of Kalispell (3½ miles northwest of the Sparks School) is reported to have drilled a water well to a depth of 56 feet, penetrating 28 feet of gravel and 28 feet of bedrock. Some of the excavated bedrock was copper- and lead-bearing quartz. The water was green and unfit for stock, consequently the well was filled in.

Mr. Hap Stringfellow reported that the Mitchell prospect, in the northern Swan Range 1¾ miles northwest of Doris Mountain, is developed by an adit of undetermined length. An 8-inch vein, striking northwest, contains chalcopyrite, malachite, and azurite. A selected specimen from the vein was assayed in 1920 and reported to contain $77 a ton in copper.

CHIEF CLIFF DISTRICT

JUMBO

The Jumbo mine is 3 miles south of Kerr Mountain on a tributary of the North Fork Dayton Creek in Lake County. According to C. B. (Bill) Adams of Proctor, it was discovered prior to 1916 and was being developed by an adit when he visited the property in 1918. After an inactive period of several years, the property was reopened in 1925-26, when several men were employed sinking a winze on the vein below the adit level, reportedly to a depth of 200 feet. According to Adams, the property has been idle since 1926.

In 1963, the adit, which trends S. 30° W., was caved at the portal, the two cabins were collapsed, and the compressor building had been dismantled. A dump containing about 50,000 tons of waste rock indicates the extent of the development work.

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

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

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

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

BIG FOUR

The Big Four is 2½ miles south-southeast of Kerr Mountain on the North Fork Dayton Creek (Flathead County). The claim was located prior to 1910, and is now held by Bill and Matt Wilhelm, sons of the original locator.

A crosscut adit striking N. 35° E. intersects a 12½-inch vein at a distance of 245 feet from the portal. The adit continues beyond the vein in Ravalli rocks on a northeast bearing for an additional 115 feet. Total adit length amounts to 360 feet.

A 75-foot southeast-bearing drift exposes the vein, which strikes N. 75° to 80° W. and dips 80° to 85° S. Vein material consists of white vuggy quartz and abundant iron oxides. The vein narrows to a few inches at the southeast end of the drift. A channel sample normal to the vein, here 6 inches wide, was collected 8 feet east of the adit-drift intersection. The sample assayed 0.11 percent copper, 0.20 ounce silver, and 0.001 ounce gold a ton. Country rock is light-gray quartzite and medium-light-gray argillite of the Ravalli Group, which strikes N. 15° W. and dips 30° E.

MOSHER

The Mosher prospect is 3½ miles east of Lake Mary Ronan, in Lake County, and is on grazing and timber land owned by Bill Adams. It was located about 1910 by Joe Mosher, who was grubstaked by Clarence E. Proctor, according to Bill Adams, who also reported that $40,000 was spent developing the prospect.

Development consists of a 25-foot shaft, now inaccessible, on the top of a ridge, and a 330-foot accessible adit striking N. 78° W., with which Mosher attempted to intersect the vein at a lower elevation. The adit is southeast of the shaft; four trenches between are now filled with debris.

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

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

The country rock is light-gray thin- and medium-bedded argillaceous quartzite and argillite of the Ravalli Group, which here strikes N. 15° W. and dips 26° E.

UNAWAH

The Unawah prospect is on the north side of Unawah Creek adjacent to Felix basin, Flathead County. It is outside the map area but within the Nyack 30-minute quadrangle, the areal geology of which was mapped by Ross (1959). The workings are east of Hungry Horse Reservoir and 21 airline miles northwest of the Spotted Bear Ranger Station. The property is developed by an 8-foot open cut and a 30-foot adit.

A 2- to 5-inch quartz vein (Fig. 51) containing malachite, chalcocite, and iron oxides in blebs and vugs strikes N. 30° W. and dips 55° S. Paralleling the right wall of the adit is a pre-mineral(?) fault, indicated by 2 inches of gouge and talc and as much as 12 inches of breccia, which strikes N. 30° W. and dips 87° S. Iron oxides, silica, and malachite locally replace argillite along bedding on the west side of the adit. A selected dump sample assayed 1.33 percent copper and 0.35 ounce silver a ton.

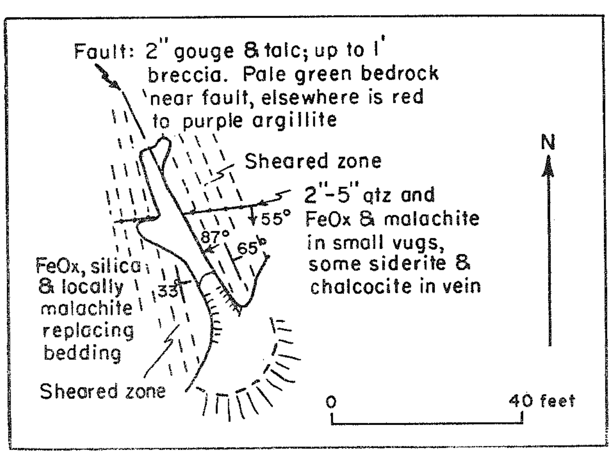


Figure 51.—Geologic map of Unawah prospect, southeastern Flathead County.

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

OTHER PROSPECTS AND VEINS

Mining activity on the South Fork of Logan Creek, 15 airline miles from the Spotted Bear Ranger Station, is believed to have commenced prior to 1896 with the location of a quartz claim named Bell of the West. The claim, 4 miles east of Hungry Horse Reservoir, was later relocated by William Corran and J. N. Orgard. In 1896 these locators patented the Little Darling and Jeanette Lodes, MS 5353 and MS 5354 (Fig. 52). The claims are presently owned by Virginia and Norman Rousselle of Kalispell.

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

The Okedale mine is reported by Walsh and Orem (1910) to be 2 miles north of Java, Montana, a small settlement 4 miles southeast of Essex on the Middle Fork Flathead River. In 1910, development amounted to a 1,000-foot tunnel intersecting a copper-bearing vein at a depth of 700 feet. Eight men were employed (1910) drifting east and west on the vein. The property was active in 1912.

One mile north of Java is the Northern mine, which is developed by several adits 200 to 500 feet long and connecting to the surface through raises. Three hundred feet of development was done in 1910 (Walsh and Orem, 1910). During 1912, eight men were employed developing a copper-gold vein.

The Lippincott mine in the Essex district, owned (in 1910) by Jack Stewart, included four claims developed by tunnels 150 feet and 200 feet in length. These adits are on a vein that contained commercial copper ore and from which several ore shipments were made. It had been planned to extend the lower adit 1,000 feet into the mountain, according to Walsh and Orem (1910), but

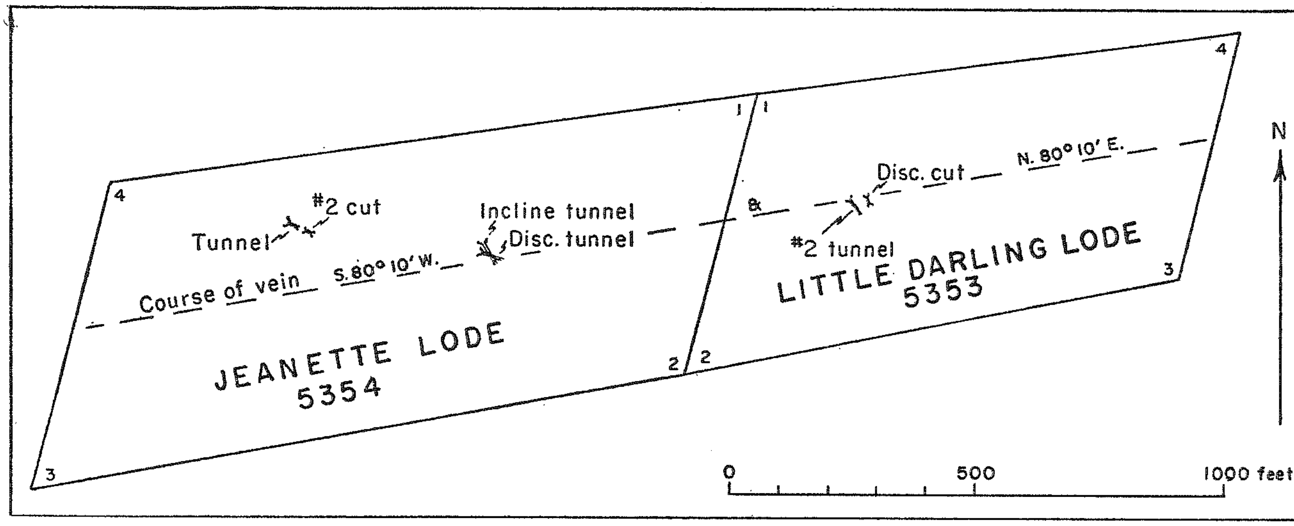


Figure 52.—Claim map of Little Darling (5353) and Jeanette (5354) lodes, southeastern Flathead County.

it is not known whether this work was ever completed.

An open cut adjacent to the Forest Service trail to Baptiste Lookout and a mile northwest of Mt. Baptiste exposes a 3-inch vertical quartz vein striking N. 84° E. The vein contains milky quartz and small masses of chalcocite and hematite. The cut is in the Grinnell Formation, which strikes N. 5° W. and dips 10° E.

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

On the Truman Creek-Blacktail Mountain road 0.4 mile south of Kerr Mountain, a 4 by 6-foot pit at the base of a cliff exposes a 17-inch quartz vein striking east and dipping 74° S. The massive white quartz vein contains vugs filled with hematite. Specular hematite is found as unaltered masses in quartz. A fault, indicated by 2 inches of shattered rock and gouge, parallels the hanging wall of the vein. Country rock is purple-gray finely banded quartzite of the Ravalli Group, which strikes N. 47° W. and dips 25° NE.

Three intersecting(?) quartz veins are exposed in a road cut at the head of Truman Creek 3 miles north of Lake Mary Ronan. Small limonite-filled vugs in shattered quartz were noted in 3½- and 1½-inch veins striking northeast and east respectively. White massive vuggy quartz, containing siderite and iron oxides, is poorly exposed in a plus 6-inch vein believed to strike northwest. Traces of copper and silver are associated with the quartz veins. Two claims, Old Dominion No. 1 and 2, were located by Gary L. Vollmer of Kalispell on October 8, 1960.

In a highway cut near Swan Lake 1 mile northwest of Swan Lake campground, a ¼-inch veinlet of earthy malachite follows bedding in Grinnell argillite. A sample of the mineral zone assayed 1.16 percent copper and 0.55 ounce silver a ton. Locally at other outcrops east of Swan Lake, malachite was found as blebs, many of which have a chalcopyrite nucleus.

A piece of lead-zinc float was reported found in 1926 during trail construction on the Helen Creek trail about 1 mile southwest of Helen Mountain, at a point where the trail turns from a northeasterly to a southerly direction. The float may have come from the divide south of Helen Mountain.

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

Barren quartz veins and veinlets striking about N. 75° W. and dipping 11° NE are exposed by three or more shallow pits on the north side of Soldier Creek north of Soldier Lake about 6½ miles northwest of Spotted Bear Ranger Station.

NONMETALLIC DEPOSITS

VERMICULITE

Rainy Creek mineral deposits were first prospected in the 1880's when base metals in quartz veins were discovered at the north end of the Rainy Creek pluton, but the presence of vermiculite was first determined by E. N. Alley of Libby while prospecting for vanadium in 1915. Small-scale vermiculite production commenced in 1925, and in 1939 several independent operations were of biotite and, if so, to determine the nature of the alteration . . . the writer favors the hypothesis that the vermiculite has been derived from biotite by the action of fluids of magmatic origin."

Another vermiculite deposit of undertermined extent is north of Fleetwood Creek toward the northern part of the Rainy Creek stock. (Fig. 54). Eight unpatented claims, the Last Chance and Last Chance No. 1 to 7, were staked by George Ottoway and Mr. Fleetwood in 1925. The property was acquired by H. J., H. L., and U. L. Poston of Kalispell in 1932. During the 1950's the property was leased and optioned by the F. &. S. Construction Company of Butte. Prior to 1964, H. J. Poston assumed complete ownership of the group.

A small irregular stock composed of porphyritic syenite and some pyroxenite intrudes the Wallace Formation east of Bobtail Creek about 10 miles north of Libby. The stock crops out on private land and National Forest land. At the southwest end of the stock, an exposure in a cut on the east side of the road exposes tremolite, biotite, magnetite, and pyroxene minerals. Some vermiculite has been reported in the cut. Development work consists of some pits in soil-covered areas near the south end of the stock.

BARITE

KOTSCHEVAR

The Kotschevar or Copper Mountain group is on Copper Mountain 5 miles south of Troy in the Troy district. The property consists of nine unpatented lode claims and three millsites (Fig. 55). The group was purchased in 1958 from James B. Robinson of Spokane, Washington, by Donald and Lendal Kotschevar of Sandpoint, Idaho, and Missoula, Montana. No production has been reported.

The property is developed by an 80-foot adit (accessible) on Vein No. 1, a 35-foot adit on Vein No. 3, and several pits and cuts on the other veins.

Three branching fracture-filling veins and one cross vein ranging from 1 to 5 feet in width strike northwest to northeast (DeMunck and Ackerman, 1958). The three branch veins dip east and the cross vein dips southwest. The barite vein on the Julia K. claim (No. 1 on map, Fig. 55) strikes about N. 20° W. and dips 44° NE, but swings to strike about N. 30° E. on the Tungsten King, Rising Sun, and Nina K. claims. It is well exposed in an 80-foot adit, where it is 30 to 40 inches wide and is composed of dense white barite, which assays 92.1 percent barium sulfate and 0.35 percent silica. A split from this vein (No. 2 on map) strikes N. 15° W. and dips 60° NE, crossing the Windjammer claim. The cross vein at the southwest ends of the Windjammer and Tungsten King claims (No. 3 on map) is 4½ feet wide, strikes N. 60° W, and dips 47° SW. It is well exposed in a 35-foot drift, where its width averages 30 inches. Some sulfides occur in this vein. The Tungsten King vein (No. 4 on map) trends N. 50° E. and dips 40° SE. It is a split off vein No. 1 and is 2 to 5 feet wide. Other veins crop out on the Buckskin and Windy Pass claims. The Buckskin vein is 3½ feet wide, strikes N. 80° W., and dips 85° N. On the Rising Sun fraction, the vertical vein (No. 1) is about 3 feet wide. All veins are in the Wallace Formation, which trends about N. 30° W. and dips 60° to 65° S.

Tom Schessler (personal communication) reported that a 3½-foot vein on the Buckskin claim contains 8 inches of quartz and barite on the hanging wall, 14 inches of yellow crystalline barite in the center, and 20 inches of brecciated barite, ankerite, and siderite on the footwall. Schessler estimated the barite content of sections of veins as ranging from 40 to 60 percent. High-grade parts of the veins may assay 85 to 95 percent barium sulfate.

KENELTY BARITE

The Kenelty barite lease is about 2 miles south of Loon Lake on the south side of a tributary of the Fisher River, in Lincoln County. Gerald Kenelty of Libby discovered the vein during logging operations in 1960 and leased the property from The Anaconda Company in 1961. The property has been inactive for several years.

Three trenches and a strip pit 175 by 18 by 5½ feet expose a barite vein along a probable strike length of about 600 feet. Width of the vein ranges from 10 to 18 feet. The vein strikes N. 65° to 75° W. and is vertical or nearly vertical at the center cut. The massive white and reddish-white barite contains minor white quartz, hematite, and sericite. South of the stripped area (Fig. 56) is a fourth cut exposing a 2½- to 3-foot vein, which strikes N. 30° E. and is vertical. The barite contains some quartz and small masses of purplish-maroon hematite and sericite. Country rock is sericitic light-gray, yellow-gray, and yellow-brown noncalcareous siltstone and argillite of the Libby Formation. Samples of barite from surface cuts have specific gravities of 4.15 to 4.20.

In 1962 about 400 tons of barite was mined and shipped by Great Northern Railway to Cal-Bar at Clear Lake, Washington. Most of the ore was broken by jackhammer and loaded by front-end loader from the northwest trench. Chunks of high-

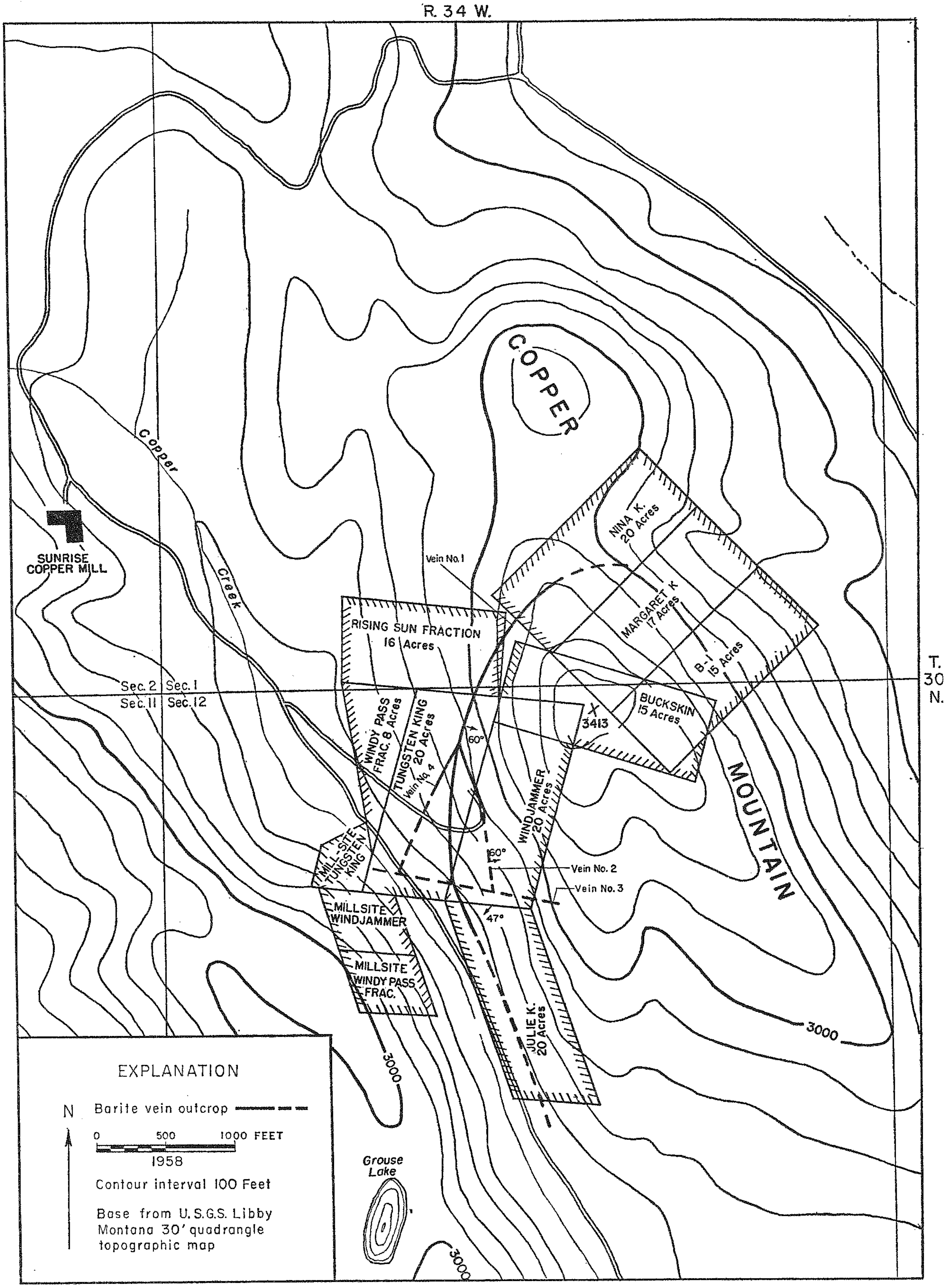


Figure 55.—Claim map of Kotschevar (Copper Mountain) barite property, Troy district.

combined under the name Universal Zonolite Insulation Company; the name was changed to Zonolite Company in 1948. In 1964 the company became the Zonolite Division of the W. R. Grace Company.

A 1,000-ton mill erected in 1948 produced 350 to 400 tons of concentrate a day. Production has been increased to 500 tons a day, and the present facilities are to be expanded. Since the middle 1920's, about 35,000,000 tons of ore and waste have been moved, at an ore-to-waste ratio of 1:1.4 (Boettcher, 1963, p. 7).

Open-pit mining methods are used, and the ore is selectively mined and loaded by power

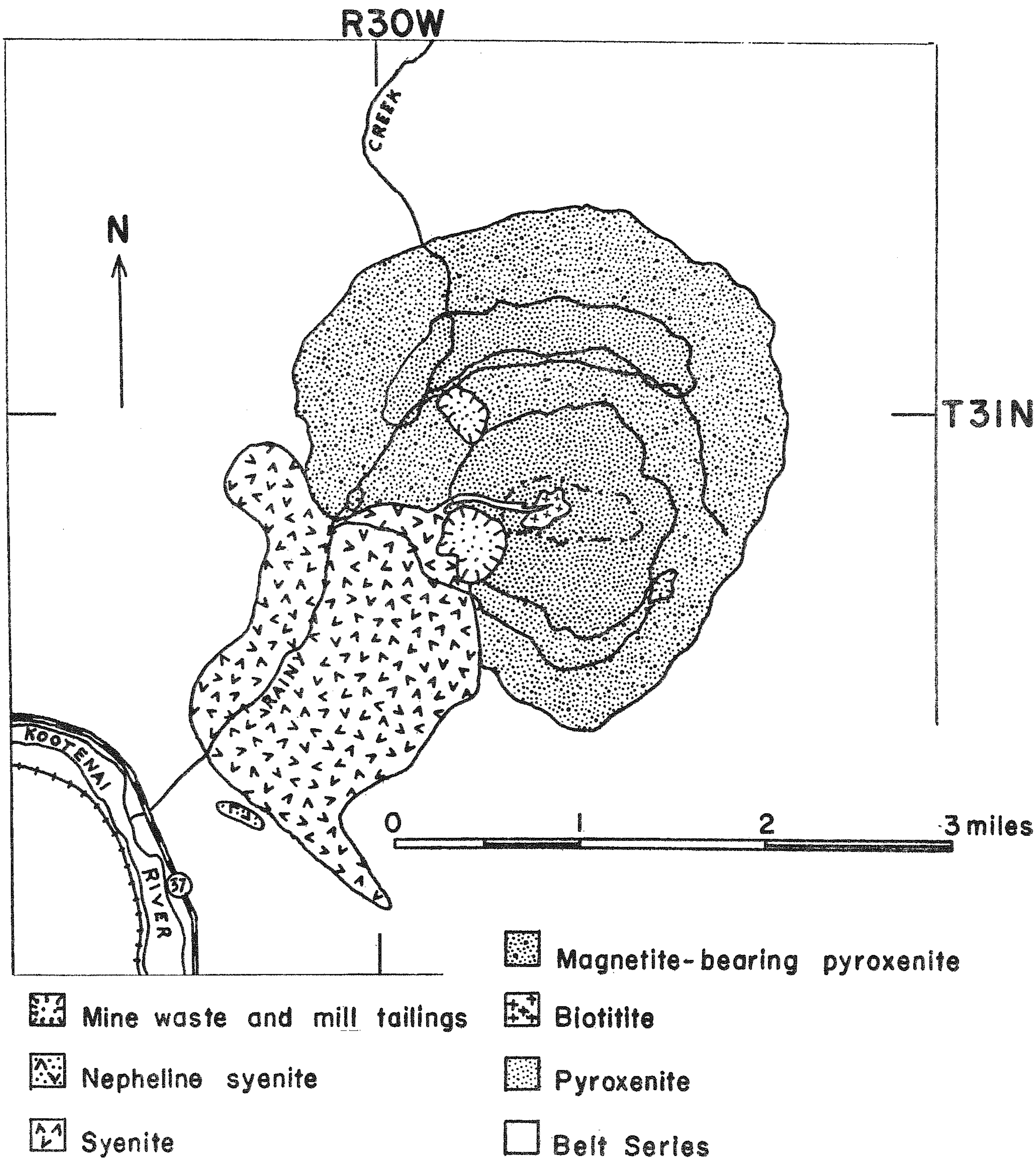


Figure 53.—Geologic map of Rainy Creek pluton, Rainy Creek district, Lincoln County (A. L. Boettcher, 1963).

shovels. Waste is trucked to a dump at the southwest end of the mine area. Milling is done by a combination of wet and dry processes, including gravity methods, flotation, and screening. The vermiculite concentrate is dried and screened to various size ranges.

The Rainy Creek intrusive body is an elongate composite stock of biotite-magnetite-pyroxenite and syenite (Fig. 53) intruding strata of the Wallace Formation within the trough of a northwest-trending syncline. An alteration halo reported to be 300 feet wide (Boettcher, 1963) consists of recrystallized and sericitized metasedimentary rocks surounding the magnetite pyroxenite; the intensity of alteration decreases outward from the contact of magnetite pyroxenite with sedimentary rocks. A border phase of the magnetite pyroxenite is magnetite rich, a grab sample of the material assaying about 16 percent magnetite.

Boettcher (1963, p. 12) described two major pyroxenite rock types; the more abundant type is very coarse grained pyroxenite composed of pyroxene (probably diopside), mixed vermiculite and hydrobiotite, and accessory fluorapatite; it contains all of the economic vermiculite in the stock. The grain size of the pyroxenite ranges from 1 cm to 2 meters or more in length, the average grain size being about 5 cm. The second, finer grained type described by Boettcher forms zones within the coarse-grained pyroxenite. It consists almost entirely of pyroxene and contains only small quantities of mixed vermiculite and hydrobiotite, apatite, garnet, magnetite, ilmenite, and sphene.

A mass of biotite, 600 by 1,000 feet, near the center of the biotite-magnetite pyroxenite intrusive body was described by Boettcher (1963, p. 13) as consisting of 90 percent biotite and the other 10 percent feldspar, pyrite, and calcite. The contact between biotite and pyroxenite is sharp. Syenitic pegmatite bodies as much as 10 feet wide intrude both biotite pyroxenite and biotite.

Bordering the biotite-magnetite pyroxenite intrusive body on the southwest (Fig. 53) is a syenite body, from which an apophysis extends into the pyroxenite. The main syenite body is coarse-grained microcline microperthite containing 20 to 30 percent muscovite. Bordering the syenite apophysis and related syenite dikes in the pyroxenite are alteration halos of tremolite after pyroxenite, which are of potential economic importance as a source of brittle asbestos. Southwest of the syenite mass is a coarse-grained nepheline syenite intrusive body containing nepheline, albite, aegirine, and microcline-perthite (Boettcher, 1963).

Post-syenite quartz veins contain uneconomic amounts of chalcopyrite, bornite, sphalerite, fluorite, pyrite, aegirine, rutile, and accessory calcite. Some opalized rock was uncovered at the west end of a lower bench in 1964.

The Rainy Creek pluton has many minerals of potential value, besides the vermiculite, which is being marketed at present. Amphibole asbestos (tremolite), the nearly pure feldspar in the syenite dikes, biotite in the biotite mass, and apatite, associated with vermiculite, pyroxene, and the magnetite-rich border phase of the biotite-magnetite pyroxenite intrusive body, may be profitable byproducts if separation can be achieved economically and if markets can be developed for these minerals.

Origin of the vermiculite is still debatable, although some investigators have concluded that it is derived from biotite through hydrothermal alteration or alteration by weathering and surface water. Boettcher (1963, p. 59) stated:

> "There is no evidence in the field or in thin section to indicate that the vermiculite (or biotite if the vermiculite was originally biotite) or the biotitite* core are alteration products of the pyroxene. Furthermore, field relationships suggest that the vermiculite (or biotite) and biotitite are older than the veins, syenite dikes, and pegmatites, and could not be alteration products associated with their emplacement . . . It is concluded that biotite is a primary constituent of the pyroxenite. The problem is to determine if the vermiculite is an alteration product

*Biotitite is a term used by Gruner (1934) and Boettcher to describe a rock composed mainly of biotite, but containing feldspar, pyrite, and calcite.

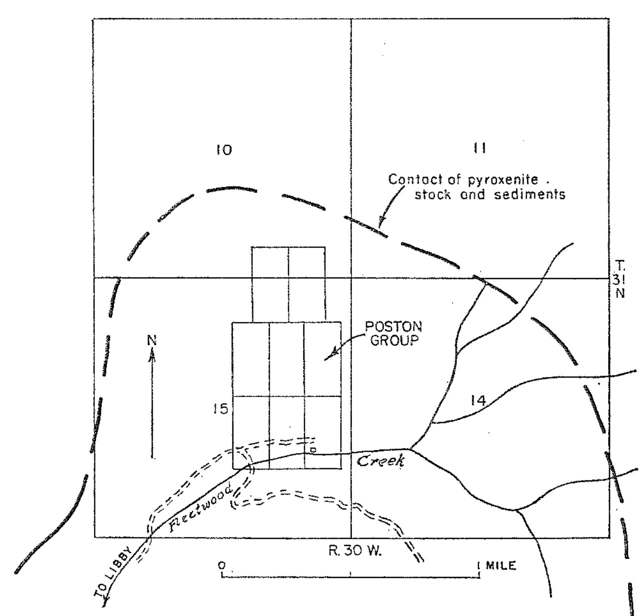


Figure 54.—Claim map of Poston property, Rainy Creek district.

grade barite as large as 1/4 ton have been mined. The truck haul to a rail siding at Libby is 38½ miles.

A 67-foot diamond drill hole collared 42 feet northeast of the vein was drilled on a 47° slope in a southwesterly direction. Material sampled between 45 and 57 feet contained 41.4 percent barium sulfate and 1.6 percent total iron; from 64 to 67 feet the recovered core assayed 47.6 percent barium sulfate and 0.8 percent total iron; the final core was barite having a specific gravity of 4.15. Poor core recovery and lack of water circulation prevented deeper drilling.

It is reported that a vein sample having a specific gravity of 4.2 assayed 3.65 percent SiO_2, 0.22 percent CaO, 1.06 percent FeO, and 0.57 percent Fe_2O_3.

BONNETT-HOERNER

The Bonnett-Hoerner barite property is at the south end of Lost Lake, 5 miles southeast of Eureka. One claim was located by Mr. Bonnett and Mr. Hoerner in 1958.

Barite veins 16, 12, and 5 inches thick are exposed in a bulldozer cut in Purcell Lava. The largest is exposed for a distance of about 50 feet at the base of the cut. The veins strike N. 65° E. and dip 30° SE, and are adjacent to a fault zone striking N. 40° E.

Development work includes an 80 by 20-foot bulldozer cut and an adit (now inaccessible) a short distance north of the cut. The dump rock at the adit is calcite-siderite gangue and Purcell Lava.

A representative sample from the three veins assayed 90 percent barium sulfate. A sample of the 16-inch vein assayed (personal communication, James P. Murphy) 86 percent $BaSO_4$.

MOEN

The Moen prospect is about 2½ miles east of Roosville, and a few hundred feet southwest of a switchback on the Burma road in northeastern Lincoln County (Fig. 37). A 40 by 4 by 4-foot trench trends N. 12° to 20° W., along a partly exposed barite vein, which dips about 70° SW. Rich-

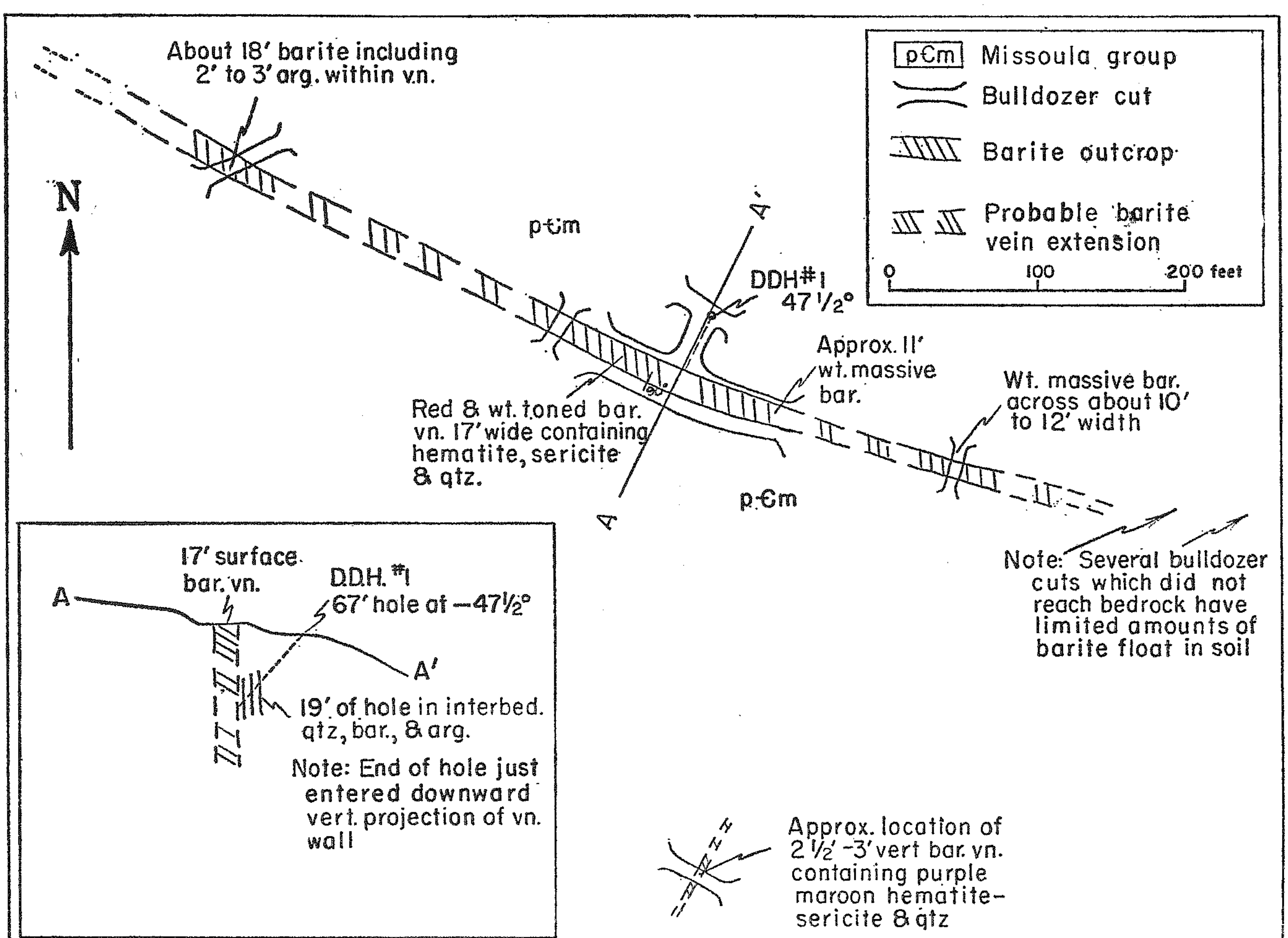


Figure 56.—Surface plan and section of Kenelty barite, Lincoln County.

ard Moen of Eureka owns the unpatented claim. Dump material contained, in order of abundance, white massive crystalline barite, quartz, iron oxides, and small amounts of chalcopyrite, tenorite, malachite, and manganese oxide. Moen reported the occurrence of a black powdery mineral identified as asbolite associated with barite in the workings. This manganese-cobalt-bearing mineral was not positively verified by Bureau x-ray tests conducted on powdery black material associated with barite specimens from the property. Selected specimens of barite from the vein assayed 60.6 percent BaO, 31.6 percent SO_3, 0.01 percent copper, 0.25 ounce silver, and 0.001 ounce gold a ton.

BOB MARSHALL WILDERNESS AREA DEPOSIT

Barite in a fissure-filling vein deposit crops out adjacent to Forest Service Trail 220 near the head of Black Bear Creek in the Bob Marshall Wilderness Area, Flathead County. The deposit is 2½ airline miles southwest of Silvertip Mountain (Pl. 3). Two northeast-trending claims, Glacier No. 1 and 2, were staked in May 1957 by Levi A. Gaustad, Melvin W. Myers, and Ben C. Trosper of Kalispell. Two cuts, one 13 by 3 by 5 feet and the other 20 by 6 by 3 feet, were dug above and below the trail.

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

At the upper cut, on Glacier No. 1 claim, barite is exposed across a width of 13 feet and neither wall is exposed; about 50 feet northeast of the pit the vein is 10 feet wide, and it narrows to a 3-foot width 100 feet from the pit. It pinches out at a distance of 135 feet. Southwest of the cut the vein is 11 feet wide where it is crossed by Trail 220, and farther southwest below the trail, the vein is 8½ feet wide in the lower cut, on Glacier No. 2 claim. The vein here strikes N. 60° E. and dips 85° S., but at the upper cut it strikes N. 78° E. Barite is exposed intermittently for a total distance of 550 feet.

Barite from the property is white to pinkish-white and maroon crystalline and massive material containing specular hematite. Some specimens contain voids previously filled with pyrite. Several percent of strontium is associated with the barite. Along the footwall of the cut (north side) a 2½-foot breccia zone contains broken angular fragments of barite, chert, and red fissile argillite in a matrix of gouge and crushed rock. A channel sample normal to the 13-foot vein in the pit contained 57.4 percent BaO and 30.6 percent SO_3.

The country rock is medium- and light-gray to very light gray, fine- to medium-grained thin-bedded sericitic quartzite interbedded with some gray-red argillite of the Missoula Group. The bedding attitude is N. 4° E., 49° E.

OTHER DEPOSITS

Barite also occurs with quartz in a 2-foot vein northeast of Green Mountain, about 3 miles southeast of the Moen deposit. Barite is associated with copper minerals in the Purcell Lava at the Peterson copper property in the Eureka district.

TALC

LYNX CREEK

The Lynx Creek (Mathews) talc, located by Tom Mathews prior to 1958, is about 2 miles southeast of Pulpit Mountain and 6 miles northeast of Troy. Talc crops out on the ridge line between China Mountain and King Mountain. Country rock is Striped Peak Formation, which strikes about N. 55° E. and dips 24° SE. The argillite and quartzite is yellow brown, yellow gray, medium dark gray, and gray green; some red-purple beds crop out near the deposit.

Fifteen vertical drill holes totaling 178 feet and ranging in depth from 2 to 43 feet (Fig. 57) were drilled to delineate a deposit 100 by 250 feet and extending to a depth of at least 40 feet. Six holes intersected gray, yellow-gray, yellow-brown,

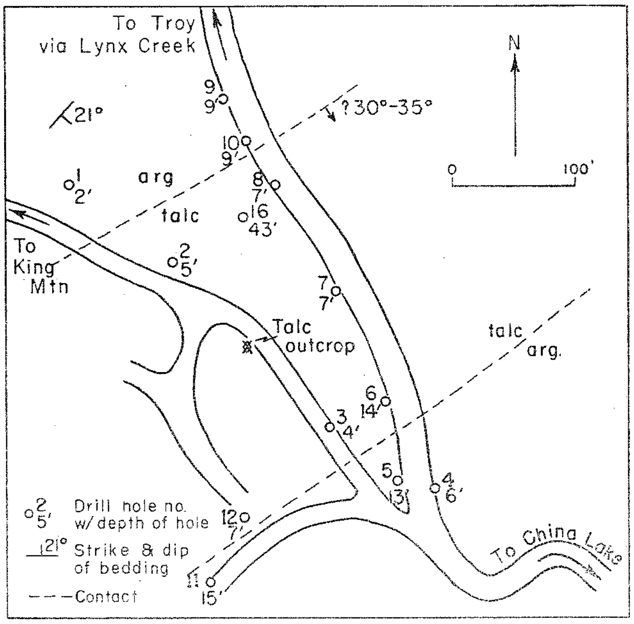


Figure 57.—Diamond drill plan of Lynx Creek talc deposit, Lincoln County.

and green-gray sericitic talc containing disseminated pyrite, iron oxides, and some quartz.

The deposit may have been formed by hydrothermal alteration of favorable Striped Peak strata.

TREMOLITE

In the Rainy Creek stock, mass-fiber tremolite of contact-metamorphic origin borders syenite dikes and quartz veins. The tremolite has formed from pyroxenite. Tremolite asbestos has economic potential for use in many applications, such as roofing, where the spinning qualities of the higher grade chrysotile is not needed. The deposit has been discussed under Vermiculite. Asbestos (tremolite, a cross-fiber variety) also occurs at the Esther May and Larue-Cripe prospects in the Yaak River area, Lincoln County.

ESTHER MAY

The Esther May claims, about half a mile northwest of Yaak in the northwest corner of Lincoln County, were staked by Romeo and Virginia Garrison in 1946. The group comprises two unpatented claims, the Esther May No. 1 and 2. In 1948 the claims were leased to Hough and Loveland of Spokane, Washington, for a period of 10 years. The lessees drilled twelve to fifteen holes near a small asbestos vein exposed on a bluff. All holes were reported to have intersected tremolite at depths of 20 to 30 feet. In 1958, H. P. Reinshagen, Sr., and H. P. Reinshagen, Jr., of Libby, leased the property for one year, with option to buy, but dropped the option.

A vertical vein of tremolite about 3 inches wide, trending N. 10° W., is exposed at the base of a bluff. Wallace country rock also strikes N. 10° W. and dips 75° NE. A second vein, 6 inches wide, has been explored by a shallow pit, in which the vein trends N. 70° W. and dips 60° SW. Autunite, a calcium uranium phosphate mineral, was reported found associated with a 3-inch syenite dikelet in a small pit at the face of a bluff. The dikelet strikes N. 70° E. and dips 70° SE. Wallace argillite has been hydrothermally altered; silica has been introduced into the surrounding country rock. A metadiorite body whose trend was not determined crops out in the area.

LARUE-CRIPE

The Larue-Cripe prospect, about 1 mile south of Roderick Butte, consists of a narrow tremolite asbestos vein exposed in two small surface pits. The vein is 3 to 6 inches thick, strikes N. 70° E., and dips 55° NW. The country rock is ripple-marked and mud-cracked Wallace argillite.

WOLLASTONITE

Two bodies of wollastonite ($CaSiO_3$) on the south side of Kennedy Gulch, 5½ miles east of Libby, strike N. 30° W. They are poorly exposed and unexplored, but each is at least 2 feet wide, and they are about a quarter of a mile apart. Country rock is the Wallace Formation.

A sample from the outcrop assayed 42 percent CaO, 45.80 percent silica, 3.90 percent Al_2O_3, 5 percent CO_2, 1.20 percent ferric oxide, and 0.50 percent ferrous oxide. Magnesium oxide was nil.

Wollastonite is used in the ceramic industry, the chemical industry, in high-grade electrical insulators, and as a nonmetalic filler.

CLAY

Clay is widespread in Lincoln and Flathead Counties; varieties include laminated glacial-lake clay, alluvial clay, and clay formed by hydrothermal alteration of igneous rock. No special study of clays was made for this report, but samples of clay from the area have been included in a continuing Bureau study of all Montana clay and shale. Samples from selected areas have been examined for their suitability as ceramic raw materials, as a source of alumina for aluminum recovery, and as possible expandable material for lightweight aggregate. Clays that have been examined are tabulated (p. 154). The results of testing are given in the publications listed, to which the reader is referred for details.

STONE

TUFA

A deposit of calcareous tufa on the D. A. Sheffler ranch near the mouth of a small tributary of the Kootenai River, about 2 miles southeast of Leonia, is approximately half a mile from the Great Northern railroad. It is estimated to be 1,200 feet long, 50 feet wide, and +12 feet deep, and assays show 85 to 90 percent $CaCO_3$. Three other deposits of tufa are on the Marion Fisher ranch 3½ miles southeast of Leonia.

Another body of calcareous tufa is poorly exposed 3 miles northeast of Loon Lake, along the road on the east side of Pipe Creek in Lincoln County. It contains about 88 percent calcium carbonate and was deposited by a spring.

Calcareous tufa near the Jack Garrison ranch on the J. Neil haul road on Callahan Creek south of Troy assayed about 90 percent calcium carbonate.

These deposits of tufa are possible sources of rock for the manufacture of quicklime.

LIMESTONE

The fault block of Mississippian(?) strata north of Eureka was sampled. A chip sample across 300 feet of the limestone near the abandoned Stahl kiln (Fig. 37) contained 98.6 percent calcium carbonate, 0.76 percent magnesia, 0.05 percent alumina, and 0.15 percent ferric iron. A 200-foot chip sample in the vicinity of the kiln contained 97.4 percent calcium carbonate, 1.48 percent magnesia, 0.53 percent alumina, and 0.15 percent ferric iron. The lime kiln was operated by Art Stahl in 1905, and bulk lime was shipped to Kalispell, Libby, and Great Falls, where it sold for $10 a ton. During a period of 2 years two men produced 6 tons of bulk lime a day and a total of 165 tons.

Cambrian(?) magnesian limestone (about 80 percent lime carbonate) is exposed 2.6 miles east of Libby bridge on U. S. Highway 2. A small deposit of Lower Paleozoic limestone crops out at "The Cliff" 12 miles southeast of Libby.

Cambrian and Devonian limestone and dolomite and Mississippian limestone crop out extensively in southeastern Flathead County. These Paleozoic limestone beds are of fair grade but are as yet accessible only with difficulty.

A grab sample of marl at Marl Lake 3 miles southwest of Fortine contains 52.8 percent calcium oxide. The marl or fresh-water limestone at this locality is composed of fragments of late Cenozoic shells.

QUARTZITE

The silica content of samples of Ravalli quartzite in Lincoln County that were analyzed ranged from 65 percent to about 86 percent, and, as in Flathead County, the silica content is too low to permit commercial use of the rock as a source of silica. In some areas the rock might be quarried for use as a building stone, especially where the red and purple colors are pleasing. In some localities it might be utilized as a source of quartz chips.

Wallace beds in the vicinity of Kootenai Falls along Highway 2 may be a source of flagstone. Natural cleavage is prominent in beds that crop out in the area.

Finely banded red and green argillite near the top of the Wallace Formation in Big Foot Creek, northeast of Troy, would make excellent flagstone. A quarter of a mile southeast of Stryker, Ravalli quartzite borders the old road bed of U. S. Highway 93. These rocks are used for decorative building stone in the Eureka area.

Middle Piegan (Siyeh Formation) carbonate-bearing rocks contain 34 to 53 percent silica, 9.80 to 13.20 percent alumina, 12.90 to 27 percent calcium oxide, and 1.20 to 6.11 percent magnesium

Sample	Age and location		Sec.	T.N.	R.W.	Publication
	Lincoln County Clays					
1	Paul Plaas, south Libby		10	30	31	Inf. Circ. 23
164	Glacial lake clay, 9 miles NW of Troy		5	32	34	Bull. 13
168	Pleistocene, 9 miles NW of Troy		5	32	34	do
169	Pleistocene, Garrison ranch, Yaak		5	35	32	do
	Flathead County Clays					
175	Nita Robbins ranch, Creston		26	27	20	do
288	Pleistocene, Kalispell		8	28	21	Bull. 27
349	East of Kalispell	NW¼	8	28	21	Bull. 45
350	Kalispell	SW¼	8	28	21	do
351	Bauska horse farm	S½	5	28	21	do
352	Bauska horse farm	SW¼	5	28	21	do
353	5 Miles S. of Creston	NE¼	3	27	20	do
354	Whale Creek	SE¼	30	36	21	do
355	Flathead River road		21	35	21	do
356	Road cut, U. S. 2	W½	12	27	24	do
376	Near Olney	SW¼	18	32	23	do
378	Hog Heaven district	SW¼	26	25	23	do
379	Hog Heaven district	NE¼ SW¼	22	25	24	do
380	Hog Heaven district		18	25	24	do
381	Dalimata ranch	SW¼	7	31	17	do
382	Burdick ranch	SW¼	18	31	22	do
384	Mrs. L. Dustin			32	23	do
461	Hog Heaven district	N.E. cor.	19	24	23	Bull. 55

oxide, plus iron oxide. Such rocks can hardly be classed as limestone, although they are often so honored. The so-called limestone could be used as building stone and ornamental stone, as the massive rock has a pleasing appearance, owing to the mottling caused by "molar tooth" or segregation structure. Cubic crystals of pyrite are a common component in outcrops west of the Rocky Mountain Trench but are not as prevalent eastward. Pyrite is a detrimental impurity in building stone. Analyses of Piegan rocks are given in the Appendix.

The hydrothermally altered banded tuff north of Niarada is quarried by the Montana Sunset Company for decorative building stone, but production is sporadic and total production is small. Currently this stone is being used for facing buildings in Libby.

Three quarries southeast of the Flathead mine have produced lightweight concrete aggregate. The rock is porous altered tuff.

FELDSPAR

The Warland stock contains abundant unaltered porphyritic and equigranular feldspar (microcline perthite and oligoclase), the feldspar phenocrysts averaging about 5 mm in length although some may be as long as 30 mm. Some quartz, iron oxides, and pyrite were observed in some specimens, but feldspar constitutes about 80 percent of the rock. The stock may provide a source of feldspar.

Potash- and soda-bearing feldspars are used in the glass, pottery, and enamel industries. A small percentage of the feldspar produced is used in the soap and abrasive industries.

GRAVEL AND SAND

Heterogeneous mixtures of gravel and a small amount of sand are associated with morainal material and stream 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 in a moraine and also obtains gravel and sand by dragline from bars in Flathead River adjacent to the U. S. Highway 2 bridge 3 miles northeast of Kalispell. The Flathead County Road Department operates a gravel pit 2½ miles east of Kalispell in 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 that filled Flathead Valley to 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 at the northeast edge of Kalispell. The Engebretson Gravel Company is excavating the eastern extension of this morainal deposit.

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 on a gentle east-dipping bench covered with second-growth lodgepole pine. Other lignite deposits are reported on the South and Middle Forks of the Flathead River, but only the North Fork area was worked to any extent (Rowe, 1906).

The North Fork mine was operated on thin lenticular beds of lignite in the lower part of the Kishenehn Formation, which here strikes N. 55° to 60° W. and dips 30° to 40° N. (Erdmann, 1947, p. 207). The mine is reached by a short access road that leaves the North Fork road at a point 6.3 miles above Big Creek Ranger Station. The installations include a tipple and six buildings, of which only two are in fair condition.

Wood (1892, p. 57) described the coal in the Flathead coal basin near Coal Creek as a fair grade of lignite having no appreciable coking qualities but containing some small nodules of mineral resin. He described a northeast-striking entry (Emerson Tunnel, 2 miles from Coal Creek) as 102 feet long in which a 45-foot section contains intercalated clay, clay shale, and coal beds. Five coal seams in the section range in thickness from 22 to 48 inches, but a sixth coal bed was reported to be 13½ feet thick. The combined thickness of these beds in the section amounted to 29 feet. Wood described six of the beds as workable. Rowe (1906, p. 49) described the lignite on the North Fork 30 miles from the Great Northern Railroad (Columbia Falls siding) as consisting of eight seams 18 inches to 12 feet thick. It was being developed by the Flathead Coal and Iron Company. Rowe reported the dip as 45°, the dimensions of the deposit as 4 miles by 2 miles, and four of the eight seams as having an aggregate thickness of 30 feet of lignite.

The North Fork mine was visited by C. E. Erdmann in 1934, at which time the daily production was 10 tons, and total production for 1933 amounted to 600 tons. Small-scale mining operations by room-and-pillar method 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 since.

The mine was developed by a southwest-bearing 325-foot entry (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, siltstone, and sandstone occurs in a zone described by Erdmann (1947, p. 206) as 13 feet thick; only the upper 6 to 8 feet of the zone was mined to extract a lignite seam 3 feet thick.

Tom Crum reported a lignite outcrop on lower Hay Creek road, 10 miles northwest of the "coal banks", and Erdmann (1947, p. 157) described a 500-foot entry striking northwest on the west bank of the Flathead River 2 miles north of Coram. 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 south of U. S. Highway 93 about 1½ miles west of Whitefish. Peat in considerable amount occurs adjacent to a creek on the Walter C. Robbin ranch 3½ miles south of Creston.

ASPHALTITE

A ¾-inch dike of asphaltite was observed on the east side of Forest Service Trail 80 along the South Fork Flathead River 2 to 2½ miles north of Black Bear Creek. The dike strikes N. 74° W. and dips 74° S., and consists of very dark gray to black shale-like rock, which burns in the flame of a match. The dike is in Devonian light-gray fetid dolomite that weathers yellow brown; the dolomite strikes N. 35° W. and dips 30° E.

Erdmann (1944) reported other dikes near the mouth of Mid Creek in sedimentary rocks of probable Devonian age.

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 younger than Belt could occur at depth beneath Flathead Valley; 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 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 (personal communication, O. A. Moen) to have drilled a well to 700 feet through gravel, sand, and clay before abandoning the drilling.

In central and northwest Montana, petroleum and gas possibilities are probably limited to the petroliferous and brecciated Devonian rocks and brecciated basal Mississippian strata having a primary crystalline porosity that can be developed into effective porosity and permeability. In addition, pre-upper Jurassic erosion and weathering affected Mississippian strata, thereby creating porous zones. Association with suitable structure also affects oil accumulation (Sloss and Laird, 1945). West of the Continental Divide, however, the brecciated zone in basal Mississippian rocks is thin, and upper Mississippian strata that might have been affected by pre-Jurassic weathering are missing. Oil and gas possibilities in Paleozoic rocks within the map areas are probably poor, because of these factors and because of the shallow depth of burial of favorable reservoir rocks.

Oil seeps are present in the valley of the North Fork Flathead River north and south of the International Border. Several wells have been drilled on the basis of these seeps.

Trauerman (1943, p. 239) stated that in 1905 some oil was discovered in the North Fork of the Flathead near Kintla Lake. American companies operating south of the International Border were the Kintla Lake Company and the Butte Crude Company. The Flathead Petroleum, British American Oil Company, and the Crows Nest Coal and Coke Company operated north of the border. Some thin and light-colored oil of very high gravity was encountered in a well drilled by the Flathead Petroleum Company. Test wells were drilled near Kintla Lakes without discovering commercial quantities of oil or gas.

CONCLUSIONS

Fissure-filling and replacement-type ore deposits commonly occupy faults in Prichard and Ravalli strata. The faults closely follow the crests and troughs of anticlines and synclines. Additional exploration along such fault fissures in favorable formations may reveal new ore deposits within the area.

Purcell Lava crops out extensively in north and northeast Lincoln County, and chalcopyrite, barite, and magnetite are locally associated with the flow. The Purcell Lava should be investigated for nickel and platinum, elements that are commonly associated with basic igneous rocks. Nickel has been reported from basic sills or dikes in the Ruby-Star Creek area west of Troy. Basic igneous rocks in southwestern Lincoln County should be examined for possible nickel content.

In the Star Meadow area in Flathead County, narrow fissure-filling veins in lower strata of the Piegan Group contain massive copper sulfide ores. The underlying Ravalli strata are believed to be a better host rock for mineral deposits, therefore they are a potential target area for larger ore deposits in this district.

In Montana Bureau of Mines and Geology Bull. 48 and 61, geochemical stream-sediment and soil-sampling projects in Lincoln and Flathead Counties delineated what are thought to be favorable areas for mineral exploration. Further investigation in the Yaak, Swamp Creek, Star Meadow, and Hog Heaven areas is recommended.

GLOSSARY OF TERMS

Anticline.—A fold or arch in rock strata in which the limbs dip away from the axis.

Argillaceous.—Rocks or substances composed of clay or having a notable proportion of clay in their composition.

Argillite.—Rock consisting of siltstone, claystone, or shale that has been to some extent recrystallized by metamorphism.

Axial plane or axial surface.—An imaginary plane or curved surface along and through the crests or troughs of successive beds involved in a fold.

Bioclastic.—Fragmented by activity of organisms.

Breccia.—Rock composed of angular fragments, contrasting to conglomerate, which is composed of rounded or subrounded pebbles, cobbles, or boulders.

Calcarenite.—Limestone (or dolomite) made of sand-size particles of coral, shell, or grains derived by erosion from older limestone (or dolomite).

Cast.—Substance filling hole formed by removal of the original material.

Clastic.—Textural term for rocks composed of fragmental material eroded from pre-existing rocks.

Colluvium.—Loose and incoherent deposits of Recent origin, including some soil but predominantly rock fragments, mantling lower part of slope not far below their source.

Concordant.—Contact of intrusive igneous body parallel to bedding or foliation of intruded rock.

Cross bedding or cross lamination.—Arrangement of laminations or strata transverse or oblique to major bedding (applies to granular sediments).

Current ripple mark.—Asymmetric ripple mark formed by current moving in one direction; has long, gentle slope in direction from which current comes and short steep slope on lee side; as material moves up gentle slope and drops down steep slope, ripple migrates downwind or downstream.

Dike.—Tabular intrusive igneous body cutting across the structure of enclosing rock.

Dip.—Angle at which a bed or planar feature is inclined from horizontal.

Discordant.—Contact of intrusive igneous body cutting across bedding or foliation of intruded rock.

Facies.—Aspect of a sedimentary geologic unit, including composition, grain size, fossil content, color, etc.

Fault.—Fracture or break along which the rock on one side has moved relative to that on the other side.

Ferruginous.—Iron bearing.

Foliation.—Laminated structure derived by segregation of different minerals into layers parallel to schistosity.

Formation.—Mappable geological unit or large persistent deposit or body of rock.

Fracture cleavage.—Parting along closely spaced parallel surfaces of fracture, independent of any parallel arrangement of mineral particles.

Graded bedding.—Grain-size gradation from coarse below to fine above, within a single stratum.

Homocline.—Persistent dip in one direction only.

Hydrobiotite.—Mixed-layer silicate composed of biotite and vermiculite.

Hydrothermal alteration.—Alteration by hot solutions or hot waters.

Intermontane.—Between mountain ranges.

Intraformational breccia.—A coarse deposit formed by almost simultaneous erosion and deposition of the strata in which it occurs.

Isoclinal.—Identical dip of strata on both limbs of a fold.

Kaolinization.—Alteration or replacement of feldspars or other minerals to form clay.

Laminated.—(Sedimentary rock) composed of layers less than 1 cm thick.

Lineation.—Parallel orientation of structural or textural features that are lines rather than planes.

Load cast.—Roll, knob, or irregularity, at base of stratum, that projects into underlying stratum; produced by differential compaction.

Meta-.—Synomymous with change; a prefix meaning change.

Metamorphism.—A change in texture or composition of a rock after solidification; produced by deformation, rise in temperature, or both.

Metasediment.—Partly metamorphosed sedimentary rock.

Mold.—Impression left by removal of shell or other organic structure, crystal, etc.

Moraine.—Accumulation of drift built by direct action of glacial ice.

Mud-chip breccia.—Angular fragments of mud-cracked surface material incorporated in overlying sedimentary rock; formed by redeposition near original site.

Oscillation ripple mark.—Symmetrical ripple marks, neither side being steeper than the other; crests are sharp and narrow; formed by oscillating movement of water or wind.

Phyllite.—Argillaceous rock intermediate in metamorphic grade between slate and schist.

Porphyroblasts.—Large grains or perfect crystals distributed in finer groundmass of metamorphic rocks.

Regression.—Seaward retreat of shoreline whereby younger strata are offset seaward.

Scour-and-fill channel.—Channel cut by down-cutting current and later filled with sediment.

Sericitization.—Development of sericite in schist or other rocks.

Shear zone.—Zone in which shearing occurred, characterized by crushed or sheared rock fragments.

Sheeted vein.—Group of closely spaced distinct parallel fractures filled with mineral matter and separated by layers of barren rock.

Sill.—Tabular intrusive ingeous body emplaced parallel to bedding or schistocity of enclosing rocks.

Stock.—Body of plutonic rock less than 40 square miles in extent; contacts generally are discordant and dip steeply outward.

Strike.—The bearing of a horizontal line in the plane of an inclined or vertical bed or structure.

Syncline.—A fold or arch in rock strata in which the limbs dip toward the axis.

Transgression.—Landward advance of shoreline whereby younger strata are offset landward.

Unconformable.—Relationship between underlying and overlying rocks that are separated by a surface of erosion or nondeposition.

Variegated.—Many-colored; connotes random distribution of colors.

Vermiculite.—Hydrous silicate of aluminum, magnesium, and iron characterized by marked expansion upon heating.

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APPENDIX

Coordinates for finding on maps (Pl. 1-3) places mentioned in this report.

To find any mine, peak, lake, or other named feature mentioned in this report and included in the mapped area, first find the name in the alphabetical listing that follows, then note the letter-number coordinate after the name. Extensive features such as rivers may have two or more coordinates.

The number part of the letter-number combination designates a vertical (north-south) row of 5-minute rectangles, which are outlined on the maps, and also indicates indirectly which map includes that row. Numbers 1-13 are on Plate 1, numbers 14-25 on Plate 2, and numbers 26-37 on Plate 3, in sequence from left (west) to right (east) across the top margin of the maps. The letter part of the letter-number combination designates a horizontal (east-west) row of 5-minute rectangles, as marked down the side of each map, starting with A at the top (north).

As an example of the use of the system, Link Lake has the coordinates C-19. As 19 is between 14 and 25, Link Lake is on Plate 2. On Plate 2, then, Link Lake can be found in the rectangle that is in the vertical row numbered 19 and in the horizontal row lettered C.

Abbot Creek H-25
Abbot Lake K-25
Abe Lincoln Mtn. D-3
Adams Mtn. F-17
Addition Creek N-31
Advent Creek F-16
Ajax placer N-8
Akinkoka Creek B-19
Alcove Creek O-30
Alder Creek G-16, I-10
Alexander Creek H-9
Alexander Mtn. G-9
Alkali Lake B-13
Allen Peak M-9
Almeda Lake I-29
Alora Creek I-25
Alpha Creek I-25
Alpha Lake I-25
American Creek A-2
American Kootenai L-7
American Mtn. A-1
Anaconda Aluminum H-24
Angel Point M-23
Antley Creek B-18
Arbo Mtn. E-4
Argosy Creek M-35
Argosy Mtn. L-35

Tetrault Lake A-12
Therriault Creek A-15
Therriault Lake A-15
Thicket Creek I-3
Thirsty Lake B-13
Thirsty Mtn. C-9
Thoma Creek A-18
Thompson Lakes L-13
Thompson River M-14, N-13
Three Eagles Mtn. K-27
Threemile Creek G-2
Three Sisters O-36
Three Sisters Creek O-36
Thunderbolt Mtn. N-29
Thunder Mtn. C-1
Tideman I-13
Tin Creek M-30
Tnuya Creek B-18
Tobacco Plains A-13
Tobacco River B-12, B-14
Tony Peak H-9
Tooley Lake A-11
Trail Creek A-20, J-25, L-8, M-32
Trapper Creek M-8
Trego D-15
Trickle Creek P-31
Trio I-3
Troy G-3
Truman Creek K-20, L-20
Trumbull Creek H-23
Tuchuck Creek A-18
Tuchuck Mtn. A-17
Tunnel Creek I-29
Turner Creek B-7
Turner Mtn. E-6
Twentyfivemile Creek K-33
Twin Creek H-4, L-14, L-32, M-31
Twin Lakes Creek M-13
Twin Meadows Creek F-14
Twin Mtn. L-32
Twin Peaks L-6
Unawah J-29
Union L-7
Upham Creek J-4
Upper Cedar Lake H-5
Upper Stillwater Lakes E-18
Upper Whitefish Lake D-19
Verdun Creek I-5
Vermiculite Mtn. G-9
Vermilion N-8
Vermilion River N-9
Victor Empire I-6
Viking M-8
Vine Creek B-6
Vogt Creek E-23
Volcour F-11
Wabumo Creek K-11
Waino's Drift M-18
Walker Creek H-22
Wall Creek O-35
Waloven Creek M-8
Wam Creek A-16
Wampoo Creek E-3
Wanless Lake L-6
Wapiti Mtn. L-10
Warex E-10
Warland F-10
Warland Peak G-12
Warrior Creek N-30
Waylett K-8
Waylett placer N-8
Wayup L-6
Weasel Creek A-17
Weasel Gulch J-3
Weasel Lake A-17
Webb Lake M-32
Webb Mtn. C-9
Weigal Creek G-13
Weigal Mtn. G-13
Welcome Spring M-19
Werner Peak F-20
West Branch E-8
West Dry Fork Creek H-12
West Fisher Creek L-8
West Flathead mine M-18
West Fork Canyon Creek N-7
West Fork Dayton Creek M-21
West Fork Granite Creek I-5
West Fork Quartz Creek F-5
West Fork Rock Creek L-5
West Fork Whitefish Creek D-18
West Fork Yaak River A-3, A-5
West Virginia H-17
Whale Creek B-18, B-20
Wheeler Creek L-28
Whistler Creek K-35
Whitcomb Creek M-33
Whitcomb Peak M-33
Whitefish H-21, H-22
Whitefish Creek E-19
Whitefish Lake G-21
Whitefish Mtn. C-18
Whitefish Peak H-21
Whitefish River H-21, J-22
White River Q-35
Whitetail Creek B-4
Whitney Creek M-12
Whoopee Creek I-2
Wigwam River A-15
Wild Bill Creek L-20
Wildcat Creek J-26
Wildcat Mtn. J-27
Wildrose Mtn. K-33
Williams L-7
Williams Creek B-16
Willow Creek N-10, 0-32
Willow Creek Pass N-10
Winkum Creek A-3
Winter Creek L-36
Wishbone Lake I-5
Wolf Creek G-14, H-14, I-11, K-26
Wolf Mtn. J-12
Wood Creek A-6
Woodfir Creek Q-34
Woods E-5
Woods Bay M-25
Wort G-20
Wounded Buck Creek J-26
Yaak Falls E-3
Yaak Mtn. F-2
Yaak River A-4, A-5, D-4, E-3, F-2
Yakinikak Creek B-18
Yellow Bay N-25
Yellow Bay Creek N-25, N-26
Yew Creek M-26
Young Creek A-10, A-11
Yukon H-17
Zero Creek C-3
Ziegler Mtn. F-10
Zimmerman Hill A-6
Zulu Creek D-6

Table 1.—Analyses of limestone and siliceous-calcareous argillite (Belt Series) and dolomite and limestone (Cambrian and Devonian).

	SY4-32[1]	SY4-35[2]	SY3-43[3]	SY3-21[4]	TL3-12[5]	TL3-1[6]	SY4-44[7]	TL3-31[8]	SY1-22[9]	TL3-41[10]	NY2-18[11]	U-14[12]	U-15[13]	1221[14]
Silica (SiO_2)	47.40	44.20	41.00	28.80	1.70	4.20	49.40	0.20	1.80	34.00	35.20			36.80
Alumina (Al_2O_3)	9.10	9.50	7.80	11.40	0.60	4.20	9.10	none	0.50	9.80	8.80	0.05	0.53	5.92
Calcium oxide (CaO)	17.80	20.00	24.20	18.60	30.60	39.00	20.60	32.00	54.00	27.00	22.50	55.25	54.57	21.03
Magnesia (MgO)	3.90	3.30	1.80	11.50	21.60	8.10	3.20	21.50	none	1.60	6.96	0.36	1.48	6.38
Carbon dioxide (CO_2)	14.60	15.20	14.40	19.60	43.50	41.20	20.30	45.50	39.80	19.00	23.80			22.71
Ferric oxide (Fe_2O_3)										1.50	2.27			1.40
Ferrous oxide (FeO)										1.20	0.39	0.15	0.15	0.85
Iron (Fe)	1.50	2.00	1.90	1.80	0.80	0.70	2.00	0.40	0.30					
Soda (Na_2O)														0.76
Potash (K_2O)														1.68
Carbon (C)														0.08
Total	94.30	94.20	91.10	91.70	98.80	97.40	104.60	99.60	96.40	94.10	99.92			97.61
$CaCO_3$	13.20	17.10	39.00	4.60			17.00					98.40	97.30	
$CaMg(CO_3)_2$	16.70	14.40	8.20	52.50	95.70		14.00							
Sp. gr.														2.784

1/ Siliceous and dolomitic calcareous argillite, Wallace Formation, sec. 35, T. 32 N., R. 31 W.
2/ Siliceous and dolomitic calcareous argillite, Libby Formation, sec. 24, T. 33 N., R. 32 W.
3/ Siliceous and dolomitic calcareous argillite, Wallace Formation, sec. 2, T. 32 N., R. 34 W.
4/ Dolomitic limestone, Wallace Formation, sec. 21, T. 32 N., R. 34 W.
5/ Dolomite, Cambrian, 2.7 miles southeast Libby Creek bridge, SE¼ sec. 15, T. 28 N., R. 30 W.
6/ Dolomitic limestone, Cambrian, SE¼ sec. 4, T. 28 N., R. 30 W.
7/ Siliceous and dolomitic calcareous argillite, Wallace Formation, sec. 16, T. 33 N., R. 31 W.
8/ Dolomite, Cambrian, 2.6 miles southeast Libby Creek bridge, SE¼ sec. 15, T. 28 N., R. 30 W.
9/ Calcareous tufa deposit, Garrison Ranch.
10/ Siliceous limestone, Wallace Formation, sec. 28, T. 29 N., R. 29 W.
11/ Siliceous magnesian limestone, Siyeh Formation, SW¼ sec. 10, T. 37 N., R. 29 W.
12/ Mississippian(?) limestone, 300-foot chip sample, sec. 1, T. 37 N., R. 27 W.
13/ Mississippian(?) high-calcium limestone, 200-foot chip sample, sec. 1, T. 37 N., R. 27 W.
14/ Siliceous magnesian limestone, Siyeh Formation, Whitefish Range (from Daly, 1912, p. 799).

Table 2.—Analyses of siliceous and calcareous argillite (Belt Series).

	SY1-2[1]	SY3-23[2]	SY3-24[3]	SY4-50[4]	PV3-10[5]	PV2-7[6]	PV2-5[7]	SY4-33[8]	SY3-39[9]	SY3-40[10]	SY3-41[11]	TL3-11[12]	TL4-31[13]	LB3[14]	SY2-11[15]
Silica (SiO_2)	66.00	47.70	44.60	54.50	59.20	53.20	64.40	56.70	44.50	48.40	46.50	67.20	51.00	39.00	54.90
Alumina (Al_2O_3)	9.40	10.50	13.70	9.80	17.20	12.80	18.15	12.40	11.70	9.90	11.60	18.20	12.40	13.20	13.50
Calcium oxide (CaO)	8.30	13.50	9.70	11.70	6.70	12.90	9.00	10.00	15.60	13.50	16.50	2.50	13.60	18.10	8.86
Magnesia (MgO)	1.80	5.20	3.40	3.30	2.70	6.11	5.56	3.60	3.90	1.60	3.00	0.40	3.50	1.20	5.94
Carbon dioxide (CO_2)		16.30	9.80	8.70				10.20	12.60	16.90	11.70	1.00	11.00	16.80	13.00
Ferric oxide (Fe_2O_3)					0.56	0.15	0.16						3.60		2.35
Ferrous oxide (FeO)					3.84	2.50	2.80						1.40		1.04
Iron (Fe)	1.60	2.30	2.20	2.20				1.80	1.60	1.50	1.80	2.80		2.50	
Phosphoric oxide (P_2O_5)						0.40	0.44								

1/ Siliceous and calcareous argillite, Wallace Formation, NW¼ sec. 3, T. 32 N., R 34 W.
2/ Siliceous, calcareous, and dolomitic argillite, Wallace Formation, sec. 11, T. 32 N., R. 34 W.
3/ Calcareous and siliceous argillite, Wallace Formation, NE¼ sec. 1, T. 32 N., R. 34 W.
4/ Siliceous and calcareous argillite, Wallace Formation, sec. 8, T. 33 N., R. 32 W.
5/ Siliceous and calcareous argillite, upper Prichard Formation, sec. 25, T. 28 N., R. 27 W.
6/ Siliceous and calcareous argillite, Siyeh Formation, sec. 1, T. 31 N., R. 26 W.
7/ Siliceous, calcareous dolomitic argillite, "Werner Peak" Formation, sec 6, T. 30 N., R. 25 W.
8/ Siliceous and calcareous argillite, Wallace Formation, sec. 22, T. 32 N., R. 31 W.
9/ Siliceous and calcareous argillite, Wallace Formation, SE¼ sec. 4, T. 32 N., R. 33 W.
10/ Siliceous calcareous dolomitic argillite, Wallace Formation, SE¼ sec. 4, T. 32 N., R. 33 W.
11/ Calcareous and siliceous argillite, Wallace Formation, sec. 4, T. 32 N., R. 33 W.
12/ Siliceous argillite, Wallace Formation, sec. 27, T. 28 N., R. 29 W.
13/ Siliceous and calcareous argillite, Wallace Formation, sec. 17, T. 17 N., R. 27 W.
14/ Siliceous and calcareous argillite, Wallace Formation, N½ sec. 20, T. 31 N., R. 29 W.
15/ Siliceous calcareous dolomitic argillite, "Werner Peak" Formation, SE¼ sec. 14, T. 37 N., R. 29 W.

Table 3.—Analyses of quartzite and argillaceous quartzite (Belt Series).

	1125[1]	SY3-38[2]	SY3-30[3]	SY3-46[4]	SY3-47[5]	SY3-48[6]	TL1-36[7]	TL1-37[8]	PV3-14[9]	LB-9[10]	SY3-4[11]	U1-9[12]	NY1-19[13]	R12-6[14]	PV3-15[15]
Silica (SiO_2)	82.10	82.20	80.70	80.10	75.50	79.30	82.60	73.20	81.00	84.40	80.00	75.20	82.20	86.00	73.80
Titanium oxide (TiO_2)	0.40											0.27			
Iron (Fe)		1.60	1.60	1.50	2.20	1.80									
Alumina (Al_2O_3)	8.86						9.20	13.10		7.50	7.20	15.10			14.70
Ferric oxide (Fe_2O_3)	0.49						2.00	3.00	0.90	1.70	1.70	1.89	1.13	0.24	1.40
Ferrous oxide (FeO)	1.38						0.80	1.20	1.28		1.00	1.91	1.57	1.50	1.28
Carbon dioxide (CO_2)										0.20					
Magnesia (MgO)	0.56						none	none		none	1.20	1.03		1.30	1.45
Calcium oxide (CaO)	0.82						0.30	1.00		0.50	1.10	1.11		1.70	1.00
Soda (Na_2O)	2.51														
Potash (K_2O)	2.41														
Water below 100°C (H_2O-)	0.05														
Water above 100°C (H_2O+)	0.37														
Phosphoric oxide (P_2O_5)	0.04														
Total	99.99														

1/ Quartzite, western phase of Creston Formation (Ravalli), Purcell Range (Daly, 1912).
2/ Quartzite, Ravalli undifferentiated, S½ sec. 23, T. 33 N., R. 33 W.
3/ Quartzite, Prichard Formation, SW¼ sec. 30, T. 32 N., R. 34 W.
4/ Quartzite, Prichard Formation, sec. 8, T. 34 N., R. 34 W.
5/ Quartzite, Wallace Formation, sec. 19, T. 33 N., R. 33 W.
6/ Quartzite, Ravalli undifferentiated, center sec. 19, T. 33 N., R. 34 W.
7/ Quartzite, Ravalli undifferentiated, sec. 21, T. 29 N., R. 28 W.
8/ Quartzite, Ravalli undifferentiated, sec. 23, T. 29 N., R. 28 W.
9/ Purple-banded quartzite, Ravalli undifferentiated, sec. 20, T. 27 N., R. 27 W.
10/ Quartzite, Ravalli undifferentiated, center sec. 3, T. 30 N., R. 29 W.
11/ Quartzite, Striped Peak Formation, sec. 36, T. 32 N., R. 33 W.
12/ Quartzite, Ravalli undifferentiated, NW¼ sec. 36, T. 35 N., R. 28 W.
13/ Quartzite, Ravalli undifferentiated, SW¼ sec. 35, T. 36 N., R. 29 W.
14/ White quartzite, Ravalli undifferentiated, sec. 7, T. 30 N., R. 25 W.
15/ Argillaceous quartzite, Ravalli undifferentiated, sec. 22, T. 27 N., R. 25 W.

Table 4.—Analyses of miscellaneous Belt rocks.

	PV3-11[1]	PV3-10[2]	PV3-12[3]	PV3-16[4]	PV3-14[5]	PV3-13[6]	PV2-7[7]	ID21550[8]*	ID-21450[9]*	ID-13550[10]*	ID-13350[11]*	ID-15250[12]*
Silica (SiO_2)	60.00	59.20	73.80	71.60	81.00	59.30	53.20	66.73	70.21	23.73	53.57	66.45
Alumina (Al_2O_3)	23.25	17.20	14.70			16.65	12.80	15.97	14.19	4.25	11.98	16.05
Calcium oxide (CaO)	1.10	6.70	1.00			4.20	12.90	0.20	0.17	36.31	6.47	0.28
Magnesia (MgO)	2.38	2.70	1.45			6.50	6.11	2.77	2.58	2.73	6.43	3.32
Carbon dioxide (CO_2)								0.10	0.11	28.61	9.37	0.11
Ferric oxide (Fe_2O_3)	1.35	0.56	1.40	1.74	0.90	0.43	0.15	0.90	1.79	0.45	1.35	1.02
Ferrous oxide (FeO)	4.04	3.84	1.28	1.80	1.28	2.80	2.50	3.70	2.22	0.99	2.67	2.54
Soda (Na_2O)								1.42	1.04	0.32	0.61	1.42
Potash (K_2O)								4.01	3.98	0.94	3.99	4.65
Phosphoric oxide (P_2O_5)		0.4					0.4	0.1	0.05	0.07	0.12	0.08

1/ Red-brown weathering argillite, Prichard Formation, sec. 31, T. 29 N., R. 26 W.
2/ Upper Prichard Formation, calcareous argillite member, sec. 25, T. 28 N., R. 27 W.
3/ Basal green quartzite-argillite, Ravalli undifferentiated, NW¼ sec. 23, T. 27 N., R. 25 W.
4/ Gray quartzite, Ravalli undifferentiated, sec. 21, T. 27 N., R. 25 W.
5/ Upper purple quartzite, Ravalli undifferentiated, sec. 20, T. 27 N., R. 27 W.
6/ Calcareous argillite, "Werner Peak" Formation, sec. 8, T. 26 N., R. 27 W.
7/ Calcareous argillite, Siyeh Formation, sec. 1, T. 31 N., R. 26 W.
8/ Green beds in Appekunny argillite, from highway above Lake McDonald, Glacier National Park.
9/ Green beds in Grinnell argillite, from highway above Lake McDonald, Glacier National Park.
10/ Siyeh Limestone, from Alpine trail.
11/ Green calcareous argillite (Snowslip Formation) near base of Missoula Group from Middle Fork of Flathead River.
12/ Green argillite of the Missoula Group, from the Middle Fork of Flathead River.

* From Ross (1959), Flathead region, Montana.

Table 5.—Production of gold and silver from placer operations, 1906-64, Lincoln County[1]/

Year	Operating placers	Ground placered (yd.)	Gold (fine oz.)	Silver (fine oz.)	Total value
1906[2]			332		$ 6,657
1907			268		5,358
1908	2		198.2		4,097
1909	1		110		2,198
1910	2		93		1,863
1911	3		189	17	3,788
1912	3		243	15	4,859
1913	3		5		101
1914	1		2		37
1915	6		126		2,527
1916	5		1		23
1917	1		74.6	6	1,493
1918	1		3		59
1919-20					
1921	2		16		325
1922-23					
1924	3		26		519
1925-28					
1929	2		10		208
1930	4		13		258
1931	3	1,000	61		1,204
1932	7		118		2,278
1933	8		186.9	17	6,358
1934	18		49.67	6	1,740
1935-36					
1937	4		153.2	13	5,360
1938[3]	9		297	17	9,496
1939[3]	7	1,100	13		455
1940	8		10.5	7	370
1941					
1942	8		41[2]		1,435
1943	2		16		560
1944	2		11		385
1945	2		7		525
1946	2		19		665
1947	1	15,680	195	11	6,810
1948-51					
1952	1		4		140
1953-56					
1957	1		4		140
1958	1	90	8		280
1959-64					
Total		17,870	2,904.07	109	$72,571

1/ Compiled from "Mineral Resources of the United States" and "Minerals Yearbook".
2/ Production figures from "Inspector of Mines Report", 1908.
3/ From Montana Bureau of Mines and Geology Mem. 26, p. 76 and 80.

Table 6.—Production of gold, silver, copper, lead, and zinc from Lincoln County[a]/ 1900-64.

Year	Operating mines	Ore (tons)	Gold (oz.)	Silver (oz.)	Copper (lb.)	Lead (lb.)	Zinc (lb.)	Total value
1900[b]/			1,350	67,181		803,585		$ 149,887
1901[b]/			2,247	40,186		300,000		111,414
1902[b]/								
1903[b]/								
1904[b]/						747,869		32,233
1905[b]/			1,101	29,905		1,415,691		127,962
1906			85					1,708
1907	1		70	2,400				2,963
1908								
1909	5		5	157				179
1910	5	208	102	126		2,619		3,185
1911	6	4,642	259	14,621		792,485		48,587
1912	4	8,719	659	21,300		1,115,000	56,800	79,885
1913	2	125	120	420		21,900		4,553
1914								
1915	2	377	234	4,058		53,305		9,256
1916	4	343	388	167	537	10,530		8,821
1917	2	62,277	1,042	91,450		3,840,000	1,805,000	591,255
1918	2	65,412	1,045	187,531	44,750	9,394,638	8,121,925	829,618
1919	2	62,019	707	163,400	38,700	6,200,000	1,106,000	637,052
1920	1	30,875	262	114,200	25,900	3,350,000	510,300	273,767
1921	3	15,011	321	50,250		997,000	11,985	83,759
1922	3	63,679	526	151,000		3,399,000		305,533
1923	2	44,982	484	75,750	7,100	2,108,000	71,510	137,558
1924	2	33,254	364	36,075	376	1,195,000	250,800	143,186
1925	3	12,624	105	9,810		508,500	332,600	80,274
1926	2	6,536	81.6	7,620	3,210	438,500	541,500	83,496
1927	3	5,002	54.3	5,503	5,015	338,000	599,000	65,050
1928	7	1,460	756	2,504	290	99,815	36,843	25,248
1929	4	1,613	65	4,940	149	1,445,000	33,600	16,002
1930	4	1,864	178	8,620	154	726,000		10,816
1931	4	123	23	105	37	6,200		761
1932	6	1,152	384.4	4,546	651	39,300		10,104
1933	9	6,987	2,219.9	13,823	1,734	108,216		55,015
1934	7	3,964	1,006.65	14,202	2,425	172,108		52,287
1935-37[c]/								476,936[d]
1938	9	1,560+	2,400	4,817	296	59,739	12,625	90,497
1939	5	14,000	1,944	11,024	4,798	83,809		79,961
1940	14	26,348	2,204	19,513	6,000	225,300	8,000	103,463
1941	7	25,255	2,357	10,274	1,400	256,000	26,400	106,544
1942	2	880+	105	2,527		114,300		13,130
1943	4	2,325+	58	1,125	1,000	44,800	51,000	12,476
1944	4	5,306+	170	5,490	2,400	222,400	236,500	54,931
1945	3	4,015	65	1,485	1,000	46,000	70,000	15,472
1946	1	450	19	297	100	10,400	19,000	4,373
1947	2	51	205	11		300		7,228
1948	1	93		298		8,200	2,100	1,947
1949	5	117+	2	211	100	20,300	15,000	5,348
1950	3	100+	83	789	500	15,800	500	5,927
1951	4	179+	37	53		8,000	6,000	3,819
1952-56								
1957	1		9	154		2,000		740
1958-64[e]								W
Totals		513,927	25,902.85	1,179,918	148,622	40,745,609	13,924,988	$4,990,768

a/ Compiled from "Mineral Resources of the United States" and "Minerals Yearbook".
b/ Production figures from Inspector of Mines Reports for 1902 to 1906.
c/ Production from Lincoln County combined with total state production.
d/ Approximate value of ore produced during this period, the total value reported to conceal individual mine production.
e/ Production for these years combined with total production.
W/ Withheld to avoid disclosing confidential data.

Table 7.—Production of gold, silver, copper, lead, and zinc from Flathead County[a]/, 1900-64.

Year	Operating mines	Ore (tons)	Gold (oz.)	Silver (oz.)	Copper (lb.)	Lead (lb.)	Zinc (lb.)	Total value
1900-20	(no production figures)							$ 28,170
1921	1	100		45,000				
1922-27								
1928	1	10,000		555,000				323,010
1929	1	10,000		900,000				476,100
1930-33								
1934	1	3,765	30	133,220	25	1,645		87,252
1935	1	18.227		536,665				385,728
1936	2	17,383	2	484,989				375,694
1937	2	21,430	2	550,128		1,615,000		520,879
1938	3	21,016	646	521,532	796	2,427,000		471,272
1939	3	26,860	614	473,846	3,404	5,533,553		603,562
1940	3	32,137	513	624,479	109,000	7,175,200		833,106
1941	3	32,552	303	665,138	59,000	5,647,000		812,433
1942	3	27,879	370	770,206	101,000	1,227,700		655,129
1943	2	20,445	624	490,050	259,700			404,081
1944	2	3,220	149	93,330	62,200	1,500	3,500	80,499
1945	1	1,437	42	40,500	6,000			31,080
1946	1	2,020	90	42,323	30,000			42,207
1947								
1948	1	30	1	32	200	1,200	5,200	1,014
1949								
1950	1	48	2	95	400			239
1951	1	300	5	401	2,000			1,022
1952	1		1	50				80
1953								
1954	1		5	200				356
1955-64[b]/								W
Total		248,849	3,399	6,927,184	633,725	23,629,798	8,700	$6,337,860

a/ Compiled from "Mineral Resources of the United States" and "Minerals Yearbook".
b/ Production for these years combined with total production.
W/ Withheld to avoid disclosing confidential data.