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PROGRESS REPORT

ON

GEOLOGIC INVESTIGATIONS IN THE KOOTENAI-FLATHEAD AREA, NORTHWEST MONTANA

1. WESTERN LINCOLN COUNTY

By

Willis M. Johns

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

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ABSTRACT

The area mapped, the south half of the Yaak River 30-minute quadrangle, is about 440 square miles and lies at the southern end of the Purcell Mountains. The ultimate purpose of the program is to map the areal geology and determine the economic mineral potential of northwestern Montana included in Lincoln, Flathead, and northern Lake Counties.

The area so far mapped is underlain by sedimentary rocks of the Belt series of Precambrian (Algonkian?) age and include the Prichard formation, Ravalli group, Piegan group (Wallace limestone and associated rocks), and the Missoula group (Striped Peak and Libby formations). Quartzites and quartzitic argillites dominate in the Prichard formation and Ravalli group. The Piegan group is characterized by limestones and argillite. The Striped Peak formation is quartzite and argillite, and the Libby formation is argillite and magnesian limestone. These rocks were formed by static metamorphism from sands, clays, and calcareous muds deposited in a shallow sea from a source to the west.

During the Laramide orogeny, Belt rocks were compressed into northwesterly trending folds. East and northeast faults, later than northwest normal faults, may be complementary shears. A fourth group strikes north-south. Faulting has been active during recent geologic times.

Gold-quartz, lead-silver-zinc, and sparse copper mineralization has occured in veins filling pre-existing faults and shear zones in metadiorite dikes and sills, and in Belt sediments during late Cretaceous or Early Tertiary times.

INTRODUCTION

That portion of northwestern Montana including Lincoln and Flathead Counties and the northern townships of Lake County comprises a mountainous, heavily forested region, which, except for the Libby quadrangle, has never been adequately mapped. Although the area has undoubtedly been inspected by prospectors on foot, as has most of western Montana, the heavy vegetal covering renders prospecting difficult, and there are large areas where mineral deposits of economic significance may yet be discovered. To explore the area efficiently for economic mineral deposits, a more thorough knowledge of the basic geology, of the types of mineral deposits to be expected, and the most favorable areas for their occurrence are needed.

Realizing these needs, officials of the Pacific Power & Light Company and the Great Northern Railway Company early in 1958 decided to co-sponsor a five-year program aimed at acquiring the basic data and stimulating prospecting in the hope that the combined effect would be to promote further economic development and thereby stimulate growth of population and business in the area. The Montana Bureau of Mines and Geology was the obvious agency to do the work, the cost of which is borne equally by both companies.

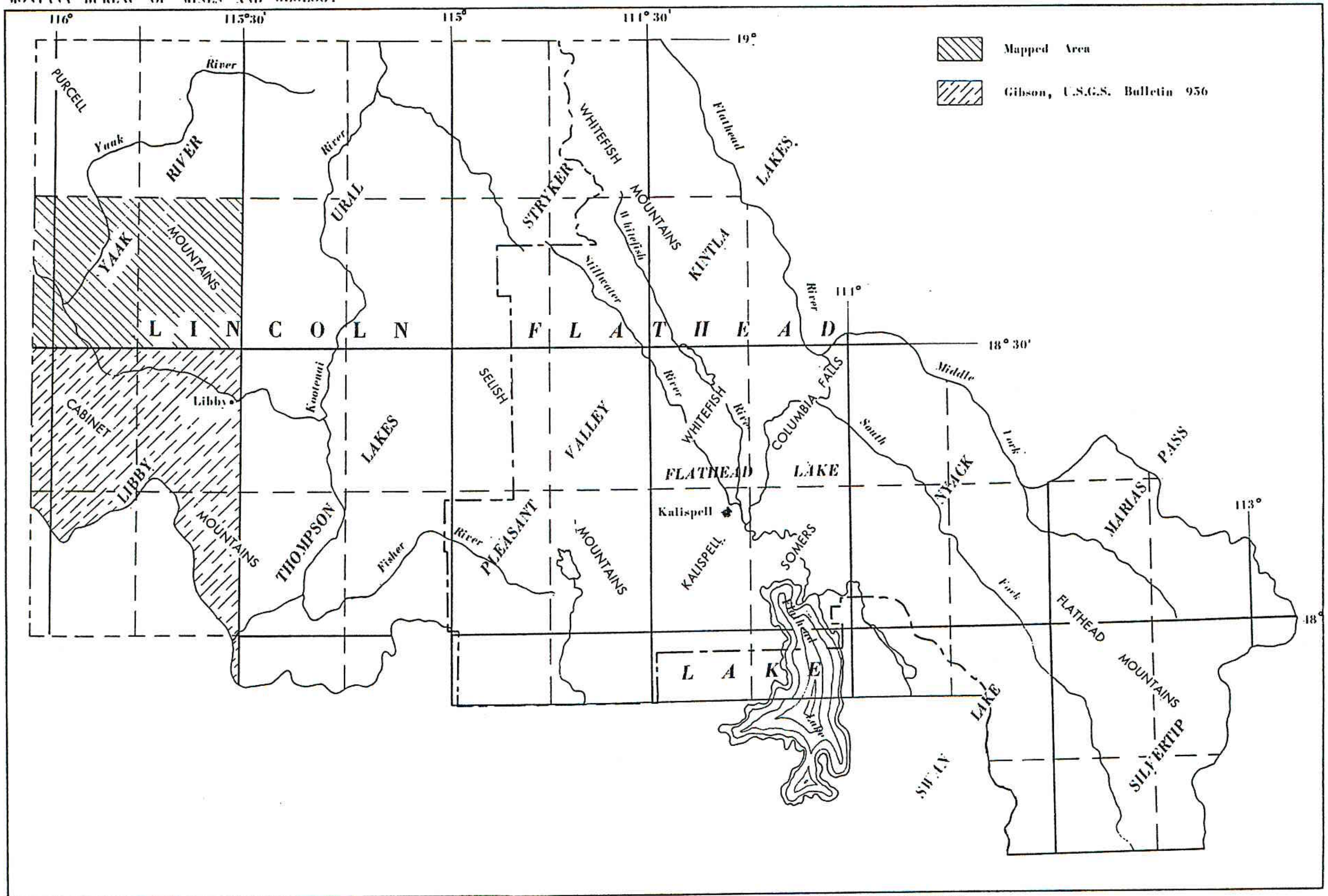
Because the survey is made by a State agency, the results must be so disseminated that all interested parties may have equal opportunity to benefit by the work should any benefit derive therefrom. For that reason, progress reports such as this will be issued annually during the life of the program. A final summary will be issued on completion of the program.

SCOPE OF REPORT

This report covers field work completed during the 1958 field season, during which the areal geology of the southern half of the Yaak River 30-minute quadrangle was mapped by reconnaissance methods. (See index map, pl. 3.) Approximately $12\frac{1}{2}$ townships comprising about 440 square miles were mapped. This represents only about one-fourteenth of the area to be mapped, but is is expected that progress will be much faster as experience is gained in the geology of the area.

Field work was started July 1st and ended November 30, 1958. Aerial photos and planimetric maps based on aerial photos were used as base maps on which to plot geology.

In November, the writer visited mining properties and owners in the Libby quadrangle gathering data on mining activities in that area since Gibson's survey, the results of which were published in 1948. (See Bibliography at the end of the report.) Only those properties for which additional information was obtained are described in this report. For descriptions of other properties the reader is referred to Gibson (1948).



INDEX MAP SHOWING LOCATION OF YAAK RIVER AND OTHER QUADRANGLES

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The writer was ably assisted in the field by Dave Dahlem. Rock and ore analyses were made by C. J. Bartzen, Bureau Analyst, and T. J. Cash drafted the maps.

The writer expresses his appreciation to the many individuals in the Troy-Libby area, who without exception, provided services and information concerning properties included in this report. Among those to whom the writer is especially indebted are A. M. Bartlett, Dan Garrison, Jack Garrison, Allen Goodgame, Jim Lyle, Elizabeth Powers, W. A. Rankin, Ernest Williams, Troy, Montana; A. Boylard, Blaze Echo, Leslie W. Leigh, H. P. Reinshagen, Clive Roark, Walter Zollers, Libby, Montana.

PREVIOUS WORK

Previous work in northwestern Montana has been of a general reconnaissance type with the exception of Gibson's survey of the Libby quadrangle, a study by Pardee and Larsen of the Rainy Creek stock, glacial studies by Alden, and Erdmann's work on possible damsite locations on the Kootenai River. (Gibson, 1948; Pardee and Larsen, 1929; Alden, 1953.) Daly (1912) mapped a narrow strip on either side of the forty-ninth parallel from the Cascade Mountains to the Great Plains. Calkins and MacDonald (1909) published reconnaissance studies of the general and economic geology respectively of northern Idaho and northwestern Montana. Schrader (1911) visited mines and placers in the Libby quadrangle. Pardee and Larsen (1929) and Perry (1948) reported on the occurrence of vermiculite in the Rainy Creek stock northeast of Libby. Kirkham and Ellis (1926) published a reconnaissance study of the geology and ore deposits in Boundary County, Idaho. In 1948 Gibson published the results of a detailed study of the Libby quadrangle with descriptions of ore deposits, and Gibson and Jenks (1941) wrote a paper concerning amphibolization of dikes and sills in that quadrangle. Alden (1953) has intermittently studied glaciation throughout western Montana since 1911, and Erdmann (1945) published detailed studies of possible damsite locations on the Kootenai River west of Libby. Lambert mapped parts of Lincoln and Flathead Counties which was later used by C. P. Ross during compilation of the State Geologic Map of Montana published in 1955.

G E O G R A P H Y

LOCATION AND ACCESSIBILITY

The area included in this report comprises the western part of Lincoln County in the northwest corner of the State. It extends from Long. 115° 30' W. westward to the Idaho line and from Lat. 48° 45' N. southward to the crest of the Cabinet Range, comprising the southern half of the Yaak River 30-minute quadrangle and the northern part of the Libby 30-minute quadrangle. The principal towns in the area are Libby and Troy, Libby being the largest and the county seat.

The Great Northern Railway and U. S. Highway 2 cross the area centrally, following the course of Kootenai River. County roads, Forest Service roads, and logging roads give access to most of the area. The Yaak River, Pipe Creek, Seventeen Mile Creek, Kilbrenan Lake, Pine Creek, and Star Creek-Leonia Loop roads are passable by passenger car. A partly paved highway extends southward from east of Troy to connect U. S. Highway 2 along the Kootenai with U. S. Highway 10 along Clark Fork. Many of the logging roads are passable only with four-wheel drive vehicles.

TOPOGRAPHY AND DRAINAGE

The mapped area lies within the Purcell Mountains which extend northward into British Columbia. Higher peaks rise to 6,590 feet, but most peaks range from 5,000 to 6,000 feet, whereas near the Kootenai River toward the southern part of the quadrangle, moderately subdued topography rises to elevations of 3,000 to 4,000 feet. The lowest point in the mapped area, about 1,820 feet above sea level, is in the Kootenai Valley at the Montana-Idaho line. The Purcell Mountains, within the quadrangle are steep, rugged, and heavily timbered. They are bounded on the east, south, and west by the Kootenai River.

The Purcell Mountains trend in a north to northwest direction parallel with the general strike of the sedimentary beds. Pipe Creek, Quartz Creek, O'Brien, and Pine Creeks occupy subordinate valleys which trend in a north to northwest direction. The valleys are approximately a quarter to a half-mile wide with moderate gradients where they emerge from the higher elevations to the terraces and benches bordering the Kootenai River. Increased gradients are characteristic of the narrower and higher valleys found throughout the quadrangle. These smaller valleys trend in numerous directions and were initially controlled by the slope of the land surface, although in some places, differential hardness of beds and faulting has affected the direction of drainage at least for short distances. Faulting in Pipe, O'Brien, and Pine Creeks has undoubtedly exerted a great influence on stream positions. Within the quadrangle, the Kootenai Valley and Seventeen Mile Valley cut traversely through the mountains in a west-northwest direction. The lower section of the Yaak River valley trends in a northeast to northerly direction; the valley near Yaak, Montana, trends about east-west; near the headwaters of the Yaak River, valleys of two of the three tributaries trend northerly.

Drainage in the Yaak River quadrangle is dendritic. Streams flow in random directions to the Yaak and Kootenai Rivers. The Kootenai River, ultimately draining the entire watershed in the quadrangle, rises in Canada, flows southward into Montana, skirting the Purcell Mountains, then back northward into Canada again to empty into Kootenai Lake and finally the Columbia River.

Erdmann (1941, p. 9) gives gradients of 4.4, 3.5, and 4.3 feet per mile for the Kootenai from Kootenai Falls to the Idaho line. The average gradient would be about 4.1 feet per mile for this section of the Kootenai River. Gradients for the streams within the quadrangle should average several hundred feet, and may in some places approach 600 to 800 feet per mile.

The average gradient of Yaak River in the mapped area is approximately 52.5 feet per mile, but gradients are higher for that section of the river between the falls and the mouth of Pine Creek. It is believed that the increase in gradient here is due to down-dropping along the southwest side of faults crossing Yaak River near Pine Creek valley.

CLIMATE AND VEGETATION

Normal precipitation for the area is about 18 inches. The U. S. Weather Bureau reports an annual rainfall of 17.30 inches at Libby for the years 1956 and 1957. Average maximum and minimum temperatures for that period were 99^{o} to -28^{o} F., with an average annual temperature of 44.5^{o} F. Seasonal snowfall was 61.50 inches.

Considerable snow remains on the north side of higher peaks until July, and Gibson (1948, p. 7) reports three small glaciers in the Libby quadrangle which have not entirely disappeared. The normal field season begins in June and terminates in late October.

The Yaak River quadrangle was formerly covered with thick stands of virgin white and yellow pine, douglas fir, tamarack or larch, spruce, and cedar. Fires in 1910 burned large stands of timber in the Yaak River and Libby quadrangles; white pine stands were replaced by second growth larch, spruce, and fir. Abundant timber is available for mining purposes. Logging is a thriving industry throughout northwestern Montana.

GEOMORPHOLOGY

The Purcell Mountains are mature mountains whose present height resulted from uplift during the Laramide orogeny. During this mountain building process the metamorphic rocks were folded and faulted by constructional processes taking place over long periods of time. Anticlines and synclines developed, erosion dissected the region, and during late Pleistocene time an immense ice sheet covered valleys and peaks throughout the area. Large rivers developed as the ice sheet melted and receded, and glacial lakes were formed in valleys blocked by ice. Small mountain glaciers formed cirques at higher elevations; however, these glaciers moved only short distances as valleys having glacial cirques and lakes at their heads are essentially V-shaped. Uplift in northwestern Montana may have continued through Tertiary and Quaternary time, and may be going on at present.

GLACIATION

Glaciation in the Libby quadrangle has been studied by Alden, Erdmann, Pardee, Gibson, and others. Alden (in Gibson 1948), describes in considerable detail glacial features in the Libby quadrangle. Daly has described the effects of glaciation in the boundary report at the forty-ninth parallel. Except for Daly's work at the International Boundary, there has been little detailed study of glaciation in the Yaak quadrangle.

Alden concluded, from broad studies throughout Montana, that glaciation occurred both during early and late Pleistocene time in the Libby area. Daly (1912, p. 578) found evidence at the forty-ninth parallel for only one glacial epoch during Pleistocene time which he correlated with the late Pleistocene Wisconsin stage of eastern glaciation. He describes the glacial till at the boundary as very fresh. Daly placed the maximum elevation at 7,300 feet, and Alden, based on this evidence, believed that the ice may have reached a maximum elevation of 6,000 feet in the Kootenai Valley. If these maximum elevations of the ice sheet are correct, at least during one period of glaciation most of the peaks in the Yaak River quadrangle were covered, with the possible exception of a few peaks at the center and north end which are in excess of 6,500 feet.

The Pleistocene period commenced about one-half million years ago, and during this time four glacial and three inter-glacial stages occurred. Leading authorities believe the last stage (Wisconsin) commenced about 50,000 years ago; the duration of this ice sheet was approximately 25,000 years.

Directions of glacial rock striations indicate the ice flowed in a southwest to south direction down the Yaak and Pipe Creek valleys. Glacial striae occur in Kootenai Valley and it is believed the ice moved up the valley. Topography antedating the Cordilleran ice sheet, at the close of Pliocene time, was probably only slightly higher than it is at present.

The Yaak River valley is U-shaped in profile. It was undoubtedly submerged at least below the 2,500-foot elevation by the glacial lake which occupied Kootenai Valley. Evidence for a glacial lake is confirmed by the presence of remmants of lacustrine sands and silts bordering the river and valley proper. Glacial Lake Missoula could have extended from the Clark Fork valley, through the Bull Lake Divide, which is at an elevation of 2,350 feet, into the Kootenai Valley. Two separate bodies of water probably existed at a later time when Lake Missoula receded below the elevation of the Bull Lake saddle.

Erdmann* states that most recent work has placed the upper-most level of Lake Missoula at an elevation of 4,260 feet; but when Glacial Lake Missoula was at this elevation, Kootenai Valley was probably still filled with glacial ice that had backed up the valley from the west.

Small alpine glaciers, on the north side of Pulpit, Skyline, and Arbo Mountains, and along the north slope of the east-west divide separating Feeder and Gunsight Mountains, formed small poorly-developed cirques at the heads of drainages. Wee Lake occupies a small glacial cirque northeast of Feeder Mountain. None of these glacial basins have been well-developed, and the glaciers did not travel for any distance below the cirques.

R O C K T Y P E S

Within the mapped area sedimentary rocks of the Belt series of Precambrian Algonkian age have been correlated with Belt rocks in the Coeur d' Alene district and Libby quadrangle. (See correlation table, pl. 3.)

All of the recognized Belt groups are present. These include, pre-Ravalli rocks (Prichard formation), Ravalli group, Piegan group (Wallace formation), and Missoula group (Striped Peak and Libby formation); although undoubtedly some rocks of the upper part of the Missoula group have been removed by erosion. Over 40,000 feet of sediments comprise the Belt series in this area.

Ransome and Calkins (1908) described and named the Belt section in the Coeur d'Alene district. During the 1930's Gibson carried the correlation from the Coeur d' Alene district to the Libby quadrangle. As the writer has extended the mapping northward to the Yaak River quadrangle, the terminology originally proposed by Calkins and continued by Gibson has been used in this report, with certain modifications proposed by Ross (1958). The base of the Prichard is not exposed in the Yaak River quadrangle, and to the writer's knowledge, nowhere else in northwestern Montana.

Paleozoic limestones, presumably middle and upper Cambrian in age, were mapped by Gibson in two small areas in the southwestern part of the Libby quadrangle, and they are also present to the east in the Whitefish Mountains; but Paleozoic rocks are missing in the Yaak River quadrangle. They may have been present at one time. An undetermined thickness of the Libby formation has been removed by erosion, so that if Paleozoic rocks were deposited, all evidence of their occurrence has since been removed. Mesozoic rocks are missing entirely in northwestern Montana.

Quaternary deposits, consisting of glacial till, terrace gravels, lacustrine sands and silts, and stream alluvium, are

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*Personal Communication

present in Kootenai, Yaak, Seventeen Mile, and Pipe Creek valleys. Terrace gravels and isolated remnants of lacustrine deposits are found on the slopes bordering the rivers and creeks. Glacial till and stream alluvium cover the valleys.

Igneous metadiorite and hornblende gabbro sills and dikes are sparsely distributed throughout most of the mapped area. The largest number of dikes and sills for any one area occur southwest of the Leonia fault in the Prichard formation. A pyroxenite-syenite stock cut by syenite dikes was mapped in Bobtail Creek.

THE PRECAMBRIAN BELT SERIES

Pre-Ravalli Rocks

Prichard formation.--Prichard rocks are present in two localities; the largest exposure is southwest of the Leonia fault in the Ruby Creek-Star Creek drainages, and the other exposures are at Sylvanite where Prichard strata form the core of the northwest-trending Sylvanite anticline.

As measured along section A-A' (see pl. 1) about 9,000 feet of quartzites and quartzitic argillites outcrop southwest of the Leonia fault. Neither the base of the formation nor the Prichard-Ravalli contact were observed here. In the Brushy Creek area west of the Leonia fault, a greater thickness of the formation is exposed. These beds represent the lowest horizons exposed in the south half of the Yaak River quadrangle. Kirkam (1930, p. 372) reports a thickness of 20,000 feet for the Prichard formation in northern Idaho. The thickness of the Prichard (9,000 feet) along section A-A' includes metadiorite sills and dikes; also possible northwest faults may cause some repetition of the beds. Prichard beds outcropping at Sylvanite belong to upper Prichard horizons.

Lower and middle strata of the Prichard are essentially quartzitic. In the Star Creek-Ruby Creek drainage the formation is a medium- to thick-bedded dark-tan to brown quartzite and quartzitic argillite with some thin beds of tan-colored sericitic sandstone and shale. The quartzite beds range from two to twelve feet thick, whereas the sand and shale horizons are from a few inches to as much as several feet thick. On exposed surfaces the quartzite and quartzitic argillite weathers to a rust or buff color, which results from oxidation of included pyrite and pyrrhotite to iron oxides. Fresh specimens contain pyrite cubes, whereas voids on weathered surfaces are often filled with hematite and other iron oxides.

Upper Prichard horizons are essentially argillaceous and sericitic. In the vicinity of Sylvanite the strata are dark- to medium-grey and tan-colored argillites and quartzitic argillites with a few beds of light-colored to grey quartzite. The beds range from a few inches to several feet in thickness.

The Prichard-Ravalli contact is conformable and gradational from a dark- to medium-grey argillite and quartzitic argillite with

	Glacier National Park Fenton and Fenton	Helena area Walcott	Missoula area Nelson	Cour d'Alene district, Idaho Ransome	Libby Quadrangle Gibson	Yaak River Quadrangle (this report)	International Boundary Daly
GROUP	FORMATION	FORMATION	FORMATION	FORMATION	FORMATION	FORMATION	FORMATION
Missoula group	Kintla Roosville Mt. Rowe Miller Peak Sheppard Purcell Basalt near base	Greenhorn Mountain Marsh Helena Empire Spokane Greyson	Pilcher Garnet Range Mc Namara Bonner Miller Peak		Top eroded Libby 6000+	Top eroded Libby 9000+	Roosvills Phillips Gateway Purcell lava at base
				Top eroded Striped Peak	2000+ Striped Peak	2000 Striped Peak	Yahk
Piegan group	Siyen	Newland	Newland	Wallace	Wallace 12,000	Piegan group (Wallace) 14,500	Moyie and Kitchner
Ravalli group	Grinnel Appekunny and Altyn Base not exposed	Chamberlain	Grinnel Appekunny	St. Regis Revett Burke	Ravalli 10,000	Ravalli group 12,000	Creston
Pre-Ravalli rocks				Prichard	Prichard 9,700+	Prichard fm. 9,000+	Aldridge
Pre-Beltian rocks		Gneiss					Gneiss and Schists Pre-Beltian (?)

Correlation of the Belt series in the Yaak River quadrangle with formations in nearby areas.

sparse beds of white or grey quartzite to the lower Ravalli strata, which are predominantly light-colored quartzites and argillaceous quartzites interbedded with some dark- to medium-grey shale and argillite.

Gibson describes Prichard rocks, in the Libby quadrangle, as the most homogeneous formation in the area. On fresh surfaces the argillite is a dark- to blue-grey which weathers to a dark red or rusty brown. Some of the argillite is finely-banded in light and dark grey; the lighter bands are commonly sandy. Sandstone horizons and occasional quartzite beds appear anywhere in the formation, however they are more numerous toward the top. The siliceous beds are light-colored, sericitic, and occasionally calcareous. Mud-cracks and ripple-marks are not common in the formation. Gibson gives a thickness of 9,700 feet for the Prichard formation in the Libby quadrangle. The Prichard-Ravalli contact is a transitional zone from 300 to 500 feet thick where the grey sandstone conformably overlies dark-grey sandy argillite.

Several thin sections of Prichard quartzite examined under the petrographic microscope were found to be composed of 75 to 85 percent fine-grained quartz particles ranging in size from 0.01 to 0.08 millimeter in diameter and averaging about 0.04 millimeters. Sericite occurs as scaly or irregular-shaped masses and flakes. Chlorite, pyrite, and detrital zircon were also identified in the section.

Ravalli Group

No attempt was made by the writer to subdivide this group into formations. Ravalli beds are essentially fine-grained quartzite, argillaceous quartzite, and argillite which outcrop to form blocky, rugged cliffs and prominent dip slopes where quartzite beds predominate. Ravalli strata outcrop east of Pine Creek valley along and beyond the divide trending through Tepee, Newton, and Cross Mountains to the vicinity of Keystone Mountain. Ravalli beds are also conspicuous east and west of Kilbrennan Lake, trending in a northerly direction along the east side of Yaak River north of Kilbrennan Lake to form prominent peaks including Gunsight, Conn, Saddle, Pleasant View, Skookum, and Independence Mountains. They were mapped in the northeastern part of the area in the vicinity of Copeland and Drop Creeks, and east of Big Creek Baldy Mountain.

A complete section of the Ravalli exposed east of the mouth of Seventeen Mile Creek is 12,000 feet thick. The section is also approximately 12,000 feet thick from the east side of Pine Creek valley through Newton Mountain to Keystone Mountain.

In the Yaak River quadrangle the Ravalli consists of light-grey to white fine-grained quartzite and sandy quartzite with interbedded dark- to light-grey argillite and quartzitic argillite in the lower and upper third of the formation. The center of the formation is predominantly a dark- to medium-grey argillite and quartzitic argillite with some light-grey to tan interbedded argillite. Middle Ravalli beds are very similar in lithology to Prichard strata in the mapped area. One bed of undetermined thickness, about 7,000 feet above the base of the Ravalli-Prichard contact, is a very dark-grey shaly argillite containing pyrite veinlets paralleling bedding planes. Ravalli rocks, especially the argillaceous quartzite, weathers rusty to buff on exposed surfaces. Pyrite is a common accessory mineral found in most horizons, and some lower strata contain biotite flakes. Magnetite particles occur in the basal part of the section. Ripple-marks, cross-bedding, and mud-cracks are sparingly present in the Ravalli rocks.

The contact between Ravalli and Wallace beds is gradational for a distance of several hundred feet and has been placed where white- to light-grey quartzite and interbedded grey argillite is overlain by thin- to medium-bedded grey argillite and calcareous argillite.

According to Gibson, the Ravalli formation in the Libby quadrangle is generally a hard and even-grained light-grey to white-colored quartzite and quartzitic sandstone forming beds from one to three feet to as much as ten or fifteen feet thick. Some interbedded sandy and shaly argillite occurs with the quartzite and sandstone. The argillite is often sericitic, ferruginous, and calcareous. Darker shales predominate toward the base of the section, and some shales contain fine-grained magnetite. Ripple-marks, cross-bedding, and mud-cracks are present in the Ravalli formation. The thickness of the Ravalli formation ranges from 7,000 to 10,000 feet in the Libby quadrangle.

The Ravalli-Wallace contact in the Libby quadrangle is gradational from a white quartzite to thin-bedded grey calcareous shale and blue-grey sandy argillite.

Petrographic thin sections of light-grey to white quartzite contain from 60 to 85 percent quartz. The particles range in grain size from 0.008 to 0.2 millimeters in diameter. The average is about 0.05 millimeter. In some slides the quartz grains are rounded to sub-rounded, whereas others show decided angularity. Pyrite, hematite, and sericite are present. Thin sections of dark- to medium-grey argillite are composed of very fine-grained quartz particles and argillaceous material. Rounded to sub-rounded particles make up about 20 to 30 percent of the rock and range in size from 0.005 to 0.02 millimeters in diameter. They average about 0.01 millimeter. In sections cut perpendicular to the bedding alternate bands of quartz grains were noted. Sericite, as fine-grained flakes and masses, is scattered randomly throughout the slide. Quartz veinlets parallel and cross the bedding planes.

Piegan Group

All strata belonging to this group have been described as the Wallace formation in the Libby quadrangle by Gibson (1948, p. 13), and the formational name was retained for mapping purposes in the Yaak River quadrangle.

Wallace formation.--The Wallace formation underlies extensive areas in the quadrangle and has a diversified lithology throughout its thickness. Horizons within the Wallace are similar to Prichard, Ravalli, and Striped Peak beds. Although the Wallace formation is heterogeneous, the greater part is a grey and green argillite or calcareous and dolomitic argillite with considerable grey, green, and tan dolomite and limestone. Along Seventeen Mile Creek, where the formation occurs as an east limb of an anticline, the thickness is 14,500 feet.

Basal Wallace beds are dark- to light-grey argillite, shale, shaly argillite, light-grey quartzite, and quartzitic argillite. The argillite and shale horizons are generally dolomitic or calcareous. Basal Wallace beds near Kilbrennan Lake are thin-bedded and banded dark- and light-grey shale and shaly argillite, usually calcareous. Interbedded grey argillite and grey dolomite and limestone are also present in the lower third of the formation. Considerable interbedded quartzitic argillite, grey argillite, and light-colored quartzite outcrops along the divide trending through sec. 3, T. 33 N., R. 34 W., and secs. 20, 29, and 33, T. 34 N., R. 34 W. Although the quartzite and quartzitic argillite is similar to Ravalli beds, the ourcrops were mapped as basal Wallace beds.

The center third of the formation is predominantly medium- to thick-bedded dark- and light-grey argillite, sandy and shaly argillite, and grey, tan, and green-banded dolomite and limestone. On Yaak Mountain about 4,000 feet of dolomite and limestone are exposed along Yaak Mountain lookout road. These calcareous rocks exhibit conspicuous molar-tooth structure. Near the base of the limestone and dolomite are several hundred feet of dark-grey argillite and quartzitic argillite. Dark-grey shale and argillite overlie the limestone. At no other place in the mapped area has this quantity of limestone occurred. It is remotely possible that the limestone and dolomite may be upper Libby horizons in a down-faulted block. An undetermined thickness of the Libby formation has been eroded in the Libby and Yaak quadrangles, and the lithology of upper Libby beds is unknown. However, no faulting of such magnitude is believed to occur in the immediate area, and the writer believes the limestone beds belong to the Wallace formation.

Upper Wallace horizons are thin- to medium-bedded grey and white dolomite, limestone, and grey sandy argillite with minor thin-bedded quartzite. Algal beds are more numerous in the upper part of the Wallace than elsewhere in the formation. In secs. 20 and 28, T. 32 N., R. 34 W., dark- and light-grey, green, and red-banded argillite and light-colored dolomitic and calcareous limestone are associated with siliceous tan- to light-colored algal horizons. The algal zones range in width from two to ten feet thick. Very conspicuous outcrops are located a mile east of Flatiron Mountain at the Pipe Creek divide. The beds in this area are grey to white limestone and quartzite, dark-grey dolomitic limestone, buff-colored shaly argillite, and buff to white algal beds. Individual layers range from an inch to two feet thick. Contrasting colors make the bluffs very distinctive. Some cross-bedding is present.

The Wallace-Striped Peak contact near Skyline Peak is gradational from a medium-bedded, medium-grey argillite and dolomitic argillite to a reddish to grey banded shaly and siliceous argillite.

Gibson (1948, p. 14) describes dominant Wallace beds as grey and green-grey sandy argillite that is commonly calcareous and dolomitic, and often slightly ferruginous. Dolomite and magnesium limestone occur in the Libby quadrangle in small amounts. Dark-grey argillite is described as thin- to thick-bedded with dark and light laminae. The sandstone often contains sericite, and nearly all specimens tested were calcareous or dolomitic.

A group of beds similar to Striped Peak horizons are present in the upper third of the Wallace formation. These beds are sericitic and ferruginous red sandstone with some grey and green layers. Abundant ripple-marks, cross-bedding, and mud-cracks occur throughout the Wallace formation.

Under the microscope sections of argillite contain very fine-grained material. All thin sections had small amounts of fine-grained quartz particles intermixed with dark-grey material.

Missoula Group

Strata belonging to this group have been mapped as the Striped Peak and Libby formations by Gibson (1948, p. 14-18) in the Libby quadrangle. The two formations are traceable at least into the south half of the Yaak River quadrangle as separately mappable units.

Striped Peak formation.--The Striped Peak formation is exposed in the south-central part of the mapped area as outcropping limbs of a north-trending syncline. The west limb continues in a northeast and northerly direction past the northern border of the mapped area, whereas the east limb is faulted out in the Pipe Creek valley.

The thickness of the formation is variable, but its minimum thickness is about 1,800, and its maximum thickness about 2,200 feet.

The formation consists of grey- and red-toned shale, argillite, and quartzitic argillite near the base, whereas middle and upper Striped Peak beds are characterized by dark and light bands of argillite, shale, and quartzite ranging from $\frac{1}{4}$ to $\frac{1}{2}$ inches wide. Other included bands or laminations are green, tan, and red-toned argillite and shale. Fine-banding is typical of Striped Peak beds in the mapped area. Red- to purple-colored sandstone and quartzite beds described by Gibson in the Libby quadrangle have not been well developed in the area to the north. The formation may be gradational in color and lithology along the strike of the beds. The predominant change from red to green may result from ferrous iron in the argillite, whereas ferric iron was believed responsible for the red color of Striped Peak beds in the Libby quadrangle. Well-developed mud-cracks and ripple-marks are found in the Striped Peak beds. No algal horizons were observed in the formation although Gibson (1948, p. 17) reports an algal dolomite near the base. The distinctive features of this formation are the fine banding and the grey, green, and red color of the argillite and shale.

The Striped Peak-Libby contact is gradational from a thin-bedded, banded, or laminated grey argillite and a dark- and light-green to tan and red shaly argillite to dark- and light-green banded argillite. A medium- to light-grey magnesium limestone is found in the lower section of the Libby formation. Near the top of the Striped Peak, a finely-banded red and green argillite occurs in some localities which is distinctive.

Gibson describes the Striped Peak formation in the Libby quadrangle as a very homogeneous dark-red and purple-colored sandstone and quartzite. The formation is thin-bedded, sericitic, and ferruginous.

Ripple-marks, mud-cracks, and cross-bedding are quite common in the Striped Peak formation.

<u>Libby formation</u>.--The Libby formation, conformably overlying Striped Peak strata, outcrops extensively in Quartz Creek and its tributaries. The formation continues in a northerly direction and occurs between Loon Lake and Pipe Creek. Flatiron and Turner Mountains are composed of Libby beds.

The formation was named by Gibson (1948, p. 17) for extensive outcrops on bluffs and ridges near Libby. In the mapped area the member occurs as the rocks in the trough of a syncline extending from the southern to the northern boundary of the mapped area.

The top of the formation has been eroded; as measured along section A-A' (pl. 1) 9,000 feet of Libby sediments are exposed between Loon Lake and West Pipe Creek fault.

The member contains thin- to medium-bedded dark- to light-grey and green argillite, shale, and quartzitic and sandy argillite. Considerable amounts of dark- to light-grey magnesian limestone are present near the base and top.

Gibson describes the formation as light- and dark-grey and green-grey argillite which is calcareous and sericitic. He also describes a less-abundant dark-grey, ferruginous magnesian limestone in which the dark material is finely-divided carbonaceous material.

TERTIARY (?) AND QUATERNARY SEDIMENTS

The unconsolidated Cenozoic sediments of the region can be roughly divided into three groups: (1) preglacial terrace deposits, (2) glacial deposits, and (3) recent alluvium. Because of the reconnaissance nature of the field-mapping, no attempt was made to map the unconsolidated deposits in detail. On the maps (pl. 1), recent alluvium is shown, but glacial and pre-glacial deposits are grouped together.

Pre-Glacial Terrace Deposits

Terrace gravels and outwash deposits cover benches in Kootenai River and Yaak River valleys on and above a terrace lying at an elevation of 2,300 feet. In secs. 19 and 30, T. 33 N., R. 34 W., parts of at least six gravel terraces border the east and west flanks of Yaak River valley below the 2,500 foot elevation. Two or more strongly dissected terraces above the 2,500 foot contour are evidently older than the well-developed terraces below. The most pronounced terrace is at an elevation of about 2,500 feet, and physiographic evidence indicates that an older stream channel may have occupied the terrace prior to Pleistocene glaciation. Thus, it would seem that at least some of the terraces are older than Pleistocene, or later Tertiary in age. However, older stream gravels are missing or are covered by later glacial deposits. Exposures of the older gravels can be seen in gravel pits in secs. 9 and 10, T. 32 N., R. 34 W. where they are overlain by glacial-lake silts.

A similar series of terraces can be observed in Kootenai Valley. Here again, any terrace deposits present are covered by glacial lake silts or other glacial debris.

Glacial Deposits

Glacial deposits are of two types: stratified glacial-lake silts and clay, and heterogeneous till or morainic material. These deposits are of unquestioned Pleistocene age. A detailed discussion of the vagaries of glaciation and glacial deposits in this area would be too long to include in a progress report such as this, but will be more fully treated in the final summary report of the program.

Lacustrine clays and silts are exposed in a railway cut three miles west of Troy, on U. S. Highway 2 west of Yaak River, and on the south flank of Kootenai Valley above Leonia. These deposits are characterized by their horizontal attitude, their bedding (1/8 inch or less), and a pale-pink or light-buff color. About a mile west of Yaak River on Highway 2, a lime-cemented pebble conglomerate occurred on the Wallace bedrock; the material was not extensive, and perhaps was formed at a temporary position of the glacial lake shore line. Typical stratified clay and silt are also found between elevations of 3,600 and 3,800 feet in secs. 15 and 23, T. 33 N., R. 32 W. about a quarter of a mile west of Loon Lake, and on Clay Creek south of Reynolds Lake near Yaak. All these exposures are but remnants of widespread deposits that were formed in glacial lakes caused by the melt water of receding glaciers.

Glacial till and morainic material cover benches on Kootenai and Yaak River valley slopes above the 2,300 foot level. Glacial moraine occurs in the SW$\frac{1}{4}$ sec. 5, T. 33 N., R. 34 W. at the junction of the North Fork and O'Brien Creeks. The material may be a lateral moraine deposited by ice moving down Kilbrennan Lake valley. Moraines in secs. 27 and 35, T. 33 N., R. 34 W. were left by a glacier passing through Tepee Springs saddle.

Recent Alluvium

Recent alluvium is found in present stream channels and as alluvial terraces bordering the Kootenai and Yaak Rivers slightly above the present river level. The alluvial plains of the Kootenai Valley are post-glacial in age.

Locally alluvium along present streams has been found gold-bearing, but placer mining in this area has not been very active.

IGNEOUS ROCKS

Precambrian Hypabyssal Rocks

Distribution.--Igneous intrusive bodies mapped as sills occur at the Duplex mine, northeast of the Oro property, near the mouth of Seventeen Mile Creek, and along lower Pipe Creek. Contacts of the igneous sills are concordant with Prichard and Ravalli sediments in the area. Erdmann (1945, p. 11) mapped wedge-shaped sills in near-vertical Prichard beds at the Katka dam site a few miles west of the Montana line. The sills appeared to disappear at depth and may have been intruded when the beds were horizontal.

Sills near Leonia, in the Libby quadrangle, in Boundary County, Idaho, and at the forty-ninth parallel have been classified as an amphibolite, or hornblende gabbro by Erdmann (1941, p. 11); a meta-diorite by Gibson (1948, p. 21); as altered diabase and gabbro to uralitized diorite by Kirkham and Ellis (1926 p. 37); and as a hornblende gabbro by Daly (1912, p. 224) respectively.

The sills are usually discontinuous and were folded during mountain building. Sills in the Yaak area range from 30 feet to several hundred feet wide; contacts are ordinarily covered so that thickness and relationship with enclosing sediments is often difficult to determine. Also, the attitude of these tabular igneous masses at depth were not observed since few mines or prospects are in areas where they are most numerous.

Two igneous bodies immediately northeast of the Oro mine were mapped as sills as they are concordant with Prichard sediments and appear to be involved in the folding. Other sills were mapped along Yaak and Seventeen Mile roads a short distance east and south of the junction of Yaak River and Seventeen Mile Creek.

Other concordant to near-concordant igneous bodies are west of the Leonia fault, northwest of Pulpit Mountain, south of O'Brien

Creek, and near Skyline Mountain. The majority of these sills may be Mesozoic intrusives that invaded Belt sediments after folding.

Locally, the sills are resistant to erosion and form bold outcrops.

Composition.--In hand specimens the rock could be classified as ranging from a hornblendite to a hornblende gabbro. The most conspicuous minerals are dark-green hornblende with some grey- to lighter-colored feldspar. Quartz is visible in some specimens. In this report, sills, dikes, and stocks of this composition are referred to as metadiorite following Gibson's terminology. Gibson (1948, p. 20) believes their original composition approached a diorite before alteration and replacement.

In thin-section pale-green hornblende with well-developed cleavage is occasionally twinned, and has been partially replaced by cryptocrystalline quartz. Feldspars of orthoclase and plagioclase, the soda-rich feldspar ranging from oligoclase to andesine in composition, have been altered along their borders. Albite and carlsbad twinning is present in plagioclase, and albite twins in the potash feldspar. Kaolinization and sericitization of feldspars is moderate to strong. Fine- to medium-grained secondary quartz and/or chalcedony was found in nearly all specimens. A grey secondary calcite, considerably twinned, fills voids, cracks, and empty spaces in the groundmass.

Another type which Gibson (1948, p. 21) recognized is a porphyritic rock with plagioclase phenocrysts, quartz, and hornblende in a fine-grained to cryptocrystalline groundmass. In thin section the groundmass is composed of feldspar, hornblende, quartz, and chlorite. Some thin sections show feldspar phenocrysts in a fine-grained to cryptocrystalline groundmass. Flow-structure parallels the alignment of the phenocrysts, and the phenocrysts have been altered at their borders.

Post-Cambrian Hypabyssal Rocks

Distribution.--Dikes were mapped at the State Line prospect, at the Oro property, and near the Black Diamond mine and Rankin prospect. Other dikes in the area outcrop east of Skyline Mountain and Loon Lake, and in upper Pipe Creek.

Dikes range in thickness from a few feet to about 200 feet. Outcrops are not too conspicuous and tend to weather more readily than the larger Precambrian sills. Dike outcrops are more continuous and have been traced for considerable distances.

Tabular igneous bodies, concordant or nearly concordant with bedding, were mapped south and southwest of Skyline Mountain, northwest of Pulpit Mountain, and southwest of the Leonia fault. Since basic igneous dikes and sills have similar composition and attitudes of these bodies are often concealed beneath soil and mantle rock, a dike truncating bedding at slight angles would be difficult to determine.

A small syenite stock whose dimensions may approach $\frac{1}{2}$ by $\frac{1}{2}$ mile, outcrops in secs. 29 and 32, T. 32 N., R. 31 W. near the mouth of Bobtail Creek. A pyroxenite facies is exposed at a road cut near the east-west line between secs. 29 and 32. Some vermiculite, biotite, magnetite, amphibole, and augite occur in the pyroxenite facies. The material is similar in composition to the pyroxenite in the Rainy Creek stock. The Bobtail Creek stock has been faulted by two northeast-trending faults and intruded by fine-grained syenite dikes.

Another stock-like mass of basic igneous rock occurs near the Rankin prospect, and a syenite stock was mapped a few miles south of Poole Lake.

Composition.--Basic igneous dikes and sills have a composition similar to Precambrian sills in the quadrangle. In hand specimens the rocks could be identified as hornblendite or hornblende gabbro. Gibson, on the basis of thin-section study, classified these basic rocks as metadiorite.

Acid igneous dikes are granitic to dioritic in composition, and some have large feldspar phenocrysts in a medium-grained groundmass of feldspar and quartz. Other fine-grained dikes are syenite. Grey and light-colored acidic dikes and stock-like bodies were mapped in Wallace and Libby sediments.

In thin-section, basic igneous dikes and sills are fine- to medium-grained rocks exhibiting weak to strong alteration and replacement. Sericite and kaolin replace feldspars. Hornblende is a pale-green mineral in reflected light; pleochroism ranges from yellow-green to blue-green to brownish-green. Cleavage and striations are well developed in some specimens. Secondary calcite is present in small amounts. Plagioclase, ranging in composition from andesine to oligocene, is sparingly present in some slides, whereas in others it is readily identified. A fine-grained matrix of secondary quartz and feldspar occasionally makes up the groundmass. Other minerals identified in slides were epidote, clinizoisite, and hypersthene (?). Accessory minerals are minor magnetite, pyrite, and illmenite (?).

Acid-igneous dike material in some thin-sections is porphyritic, and consists of feldspars with small amounts of quartz. Feldspars exhibit carlsbad and carlsbad-albite twinning. Some orthoclase is present, however most feldspar is plagioclase ranging in composition from albite to oligocene or andesine. Accessory magnetite is present. Some slides have clear feldspar, whereas other, such as slides from the dike and stock-like body south of Poole Lake, have abundant amounts of limonite that obscure minerals in the section. Some acidic dikes approach a syenite in composition. Other slides are more basic and may approach uralitized diorite. Medium-grained placioclase with minor orthoclase is fresh in some slides, and strongly altered in others. Other minerals are quartz, hornblende, augite (?), epidote (?), and biotite. Accessories are pyrite and illmenite (?). The groundmass may consist of cryptocrystalline femic minerals, or in some specimens, of quartz and feldspar.

Stocks in Wallace sediments range in composition from metadiorite to porphyritic syenite such as the Bobtail intrusive. The Bobtail stock is described in detail by Gibson (1948, p. 29-32).

Age of Igneous Rocks

The age of intrusives in the Yaak and Libby quadrangles is difficult to determine since rocks younger than the Belt series are missing in the quadrangles with the exception of small outcrops of Cambrian limestone in the south end of the Libby quadrangle.

The age of igneous intrusive bodies, with the exception of those sills believed to be of Precambrian age, probably intruded the Belt series during the Laramide orogeny. Dating of this orogeny may be early as Jurassic or as late as early Eocene.

S T R U C T U R A L   G E O L O G Y

SEDIMENTARY ROCK STRUCTURE

Folding during the Laramide orogeny buckled Belt sediments in the Yaak River quadrangle into anticlines and synclines whose axes trend in a northwest direction throughout the west half of the mapped area, whereas in the east half, the fold axes strike slightly west of north to a northeasterly direction. Both broad and tight symmetrical and asymmetrical folding is present throughout the area. Axial planes of the tighter folds, some nearly isoclinal, dip east or west, whereas broad folds have vertical to near-vertical axial planes. Northwest faulting has displaced fold axes in the Pipe Creek area, along the Kootenai River, and in the Star Creek-Ruby Creek drainages. An anticline, interpreted to be a fan-fold, was mapped in a fault block immediately east of the West Pipe Creek fault. (See section A-A', pl. 1.)

Sylvanite Anticline

The major fold in the area is the Sylvanite anticline; a broad symmetrical fold, that strikes N. 30° W. and plunges to the southeast. It is more properly described as an anticlinorium since smaller folds occur on the flanks of the structure. The Sylvanite anticline is named because the trace of the axial plane passes west of the Sylvanite Ranger Station. It extends from Skyline Mountain, through the Sylvanite district, and passes out of the area to the northwest. The Prichard formation forms the core of the anticline northwest of Sylvanite. Ravalli and Wallace strata occur on the flanks and on the south-eastward-plunging nose. The crest of the structure was broken by longitudinal faults and other tension breaks intersecting the axis at slight angles. The south end of the anticline is cut off by the Northeast Skyline fault. In the Yaak Mountain area, which may represent the southwest limb of the fold, several monoclines occur. Northward from the junction of Yaak River and Seventeen Mile Creek, outcropping Ravalli and Wallace sediments form the east limb of the Sylvanite anticline.

Kootenai River Anticline

The Kootenai anticline, named by Erdmann (1945, p. 13), closely parallels the course of the Kootenai River from Troy northwest to the Montana-Idaho line, and parallels the Leonia fault throughout the southwestern part of the quadrangle. The general strike of the axis is N. 30° W.

The folded structure is a tight asymmetrical anticline whose axial plane dips east in the Star Creek area. Smaller parallel-trending anticlines and synclines were mapped east of the structure. East-west faults have displaced the Kootenai River anticlinal axis north of Ruby Creek, the north side moving east. Erdmann (1945, p. 69) suggests that the northward shift of the Kootenai anticline south of the map area (mapped as the Troy anticline at the Troy dam-site) may have been caused by a northeast fault (possible southwestern extension of Skyline fault) at the Troy bridge. The shift of the anticlinal axis amounts to more than 2,000 feet with the northwest side moving northeast.

Quartz Creek Syncline

The Quartz Creek syncline, named because the trace of the synclinal axis of the fold passes west of the main branch of Quartz Creek, trends approximately N. 30° E., to the Pipe Creek valley. The fold axis is lost in faulting on Pipe Creek. It is a broad, open fold with Libby strata exposed along the axis and Striped Peak beds along both flanks. Smaller folds may occur on the synclinal limbs of the major fold.

Other Folds

Northeast and southwest of Kootenai River tightly-folded symmetrical and asymmetrical anticlines and synclines trend in a northwest direction. The trace of the axial planes strike from N. 10° to N. 30° W., and are vertical or dip at high angles to the east.

Sedimentary structure in and east of Pipe Creek has been obscured by faulting. Sedimentary beds were folded into tight near-isoclinal folds broken by northwest-striking faults approximately paralleling the fold axes. The effect of intense formation decreases eastward, and in the vicinity of Copeland Creek, Drop Creek, and Big Creek Baldy Mountain, broader folds trending north to northwest appear. The axial plane of the anticline that crosses Big Creek Baldy Mountain dips easterly.

Thick siliceous formations, such as the Prichard and Ravalli, would offer greater resistance to folding than thinner less indurated sediments of the upper Belt series. The Ravalli formation on Big Creek Baldy Mountain may have acted as a buttress so that the less-resistant Wallace formation in the Pipe Creek drainage was folded into sharp near-isoclinal synclines and anticlines; the Wallace formation in the area absorbed most of the principal stress in this particular location. Broader folding took place in Ravalli beds to the east.

IGNEOUS ROCK STRUCTURE

Stocks

Bobtail Creek stock.--A small syenite stock outcrops west of Bull Creek east of the Quartz Creek syncline. The stock is in Wallace sediments on the east limb of the syncline. Wallace beds strike north and dip west.

Another small stock-like syenite outcrop lies two miles south of Poole Lake. This outcrop may be a dike, since field relationships are obscured by soil and mantle rock. A dike was mapped nearby.

Sills

Sills in the quadrangle are found in Prichard, Ravalli, and Wallace strata. Sills were not mapped in sediments younger than Wallace. Sills are intrusive into lower Belt sediments along possible planes of weakness, such as pre-existing faults or sheared zones.

Dikes

Dikes are found throughout the Belt series, including the Libby formation. The greater number of dikes approximately parallel the strike of the sediments, although they do not necessarily dip in the same direction.

Sedimentary structure appears to be only indirectly responsible for sill and dike emplacement; faulting more likely provided structural control.

FAULTS

Northwest faults are the oldest and most persistent faults in the mapped area. These strike N. 20° to 30° W. and dip steeply to the northeast or southwest. Included in this group are the Leonia fault, Pine Creek-O'Brien Creek fault, Kilbrennan Lake-Savage Lake fault, Poole Lake fault, West Pipe Creek fault, and the Pipe Creek fault.

The second group, striking from N. 70° E. to east, displace northwest faults and folds. This group has flat to near-vertical dips. That movement had reoccured during recent geologic time is suggested by displacement of Pleistocene glacial lacustrine and till deposits along the trend of these faults. Fault traces are easily recognized on aerial photographs, whereas fault traces of the other groups are often obscured by erosion and are difficult to determine.

A third group, believed to be later than northwest and east-west faulting, strikes N. 30° to 50° E. The relationship between this and other groups is not clear; from inconclusive evidence it is believed that northwest and east-west faults antedate this group, or northeast and east-west faults may be contemporaneous. Northeast faults have not been traced for long distances, although the writer believes the fault traces extend for greater lengths than shown on the geologic map (see pl. 1). The Skyline fault is included in this group. Faults of this group have moderate to low-dipping fault planes.

Three north-south trending faults have been mapped in the area. One fault, a mile east of Roderick Mountain strikes north. An east-west fault was displaced by a north-striking fault at a point two miles north of the mouth of the Yaak River. Another north-south fault displaced Libby beds in Quartz Creek. These were the only north-trending faults mapped in the area.

Although folding and faulting may have been nearly contemporaneous, all large faults in the quadrangle were later than the folding, and in many places displace folds.

Description of Faults

Leonia fault.--The Leonia fault, named by Calkins, has been described by several writers. Calkins (1909, p. 53) describes it as a steeply dipping reverse fault trending north-northwest, with a throw of more than 15,000 feet. Gibson (1948, p. 41) traced the fault for a distance of ten miles in the Libby quadrangle and believed it extended southward. He observed it underground in the Liberty mine as a vertical gouge and breccia zone twenty feet wide with downthrow on the east and a displacement of at least 26,000 feet. Kirkham (1930, p. 367) described the fault as a reverse fault extending continuously from the Kootenai River in Canada, through Boundary County, Idaho, to the Clark Fork River. In British Columbia this fault has an apparent vertical displacement of 35,000 feet through the Belt series and an additional 10,000 feet of interbedded basic sills.

In the Yaak River quadrangle the Leonia fault was mapped for a distance of ten and one-half miles from Brushy Creek to the Kootenai River at the Montana line. Surface expression is poor although several swamps are along its trend. It follows the Kootenai River for a short distance before entering Idaho. The trace of the fault is straight throughout most of its strike length. It strikes N. 25° to 30° W. and dips vertically or at a high angle to the west. A displaced segment, bounded by two east-striking faults, was mapped on Star Creek. It is a reverse fault along which the west side has moved up relative to the east side.

Prichard argillaceous quartzite and Wallace calcareous argillites and dolomitic limestones occur on the west and east side of the structure respectively. In most places the fault follows the strike of the beds, although in some localities it intersects bedding at a slight angle. The apparent vertical displacement of the Leonia fault in the Star Creek-Ruby Creek area is believed to be through 32,000 feet of Belt sediments including basic sills and dikes. Horizontal displacement was not determined. Two basic igneous bodies mapped as metadiorite and hornblendite, may have filled close-parallel fissures in a fracture zone adjacent to the Leonia fault.

Pine Creek-O'Brien Creek fault.--This structure, in part inferred, lies beneath the gravels in O'Brien Creek, crosses Yaak Mountain, and continues northwest through Pine Creek valley beyond the State line. The fault strikes N. 30° W. and parallels the strike of Wallace and Ravalli beds.

Evidence for the occurrence of the Pine Creek-O'Brien Creek fault in the Yaak quadrangle is the alignment of O'Brien and Pine Creek valleys and range fronts, faceted ridges along Pine Creek valley, a zone of sheared Wallace sediments with abrupt changes of dip on either side of a depression near the summit of Yaak Mountain, and a sheared zone over several hundred feet wide containing gouge and shattered rock where the fault crosses Yaak River.

The fault was mapped as a normal high-angle to vertical fault with the southwest block downthrown several thousand feet. The block between the Leonia and Pine Creek-O'Brien Creek faults is graben-like.

This fault is displaced to the east for a few tens of feet on the north side of east-west faults near Yaak River and in O'Brien Creek. A basic-igneous dike filled the fault, or a sheared zone adjacent to the fault, at the Black Diamond mine.

Kilbrennan Lake-Savage Lake fault.--The Savage Lake fault has been described by Gibson (1948, p. 44) as an inferred structure based partly on physiographic and partly on structural evidence. In the Libby quadrangle it was observed at only one place, the Crater Lake prospects, where it strikes north, is vertical, and is 40 feet wide with downthrow to the west. A persistant metadiorite dike follows the fault zone. Erdmann (1941, p. 14) extended the Savage Lake fault across the Kootenai River. The fault crosses the Kootenai River about a mile west of the mouth of Koot Creek.

The Kilbrennan Lake-Savage Lake fault parallels the trend of the Pine Creek-O'Brien Creek fault, and lies about one and one-half miles northeast. Between Hummingbird and Lynx Creeks surface expression for the fault is poor or nonexistant; however, to the north, Lake Kilbrennan and a smaller lake occupy a trough-like valley, the trend of which suggests structural control. The fault continues northwest to cross Yaak River about two and one-half miles below Yaak Falls.

Evidence for this fault is displacement of the Ravalli contact across the small lake mentioned above. The west block moved down displacing the Ravalli contact to the northwest. Another exposure occurs on Yaak Road in the SE$\frac{1}{4}$ sec. 18, T. 33 N., R. 34 W. where two segments of the fault, 12 and 15 feet wide, are separated by an 8-foot basic dike. The segments strike N. 30° W. and dip 45° S. The fault parallels the Ravalli beds in the area. The dike filled the fault zone, and the two segments may belong to a single structure. The dike and fault zone contain small quartz veinlets and abundant iron oxides; small northeast-trending shears and post-dike slips cross the structure.

Horizontal displacement of the Ravalli contact does not exceed 4,000 feet and may be less. Vertical movement appears to be smaller than horizontal displacement.

Poole Lake fault.--The Poole Lake fault strikes N. 20° to 30° W. and dips steeply eastward. It follows the left flank of Pipe Creek valley and was mapped to Flatiron Mountain. At one exposure, in the SW$\frac{1}{4}$ sec. 22, T. 32 N., R. 31 W., a 20-foot fractured zone contains clay gouge and shattered rock. Abundant limonite and a few quartz veinlets were found at this exposure. About two and one-half miles north of Turner Mountain, it is believed the fault zone was intruded by a basic igneous dike. To the south it probably joins the Pipe Creek fault at the boundary of the Libby and Yaak quadrangles.

The fault parallels the strike of Wallace and Libby sediments, or has truncated sediments at small to medium angles. The fault is normal with the downthrow side to the east. Actual displacement is unknown.

Pipe Creek and West Pipe Creek faults.--The Pipe Creek fault follows Pipe Creek valley in the southeastern part of the mapped area, continues up Shafer Creek, crosses Bearfite Creek two miles east of Pipe Creek divide, and follows the south fork of the Yaak River in a northwest direction. The fault cuts Wallace beds throughout most of this distance, however near Zulu Creek it is a fault contact between Wallace beds to the east and Libby beds to the west. The fault strikes from N. 10° to 25° W., is a high-angle structure dipping west and is one of the larger faults in the area.

The Pipe Creek and South Fork valleys are structurally controlled by faulting. Evidence for the fault is the linear trend of Pipe, Shafer, and South Fork valleys, abrupt changes in strike and dip of Wallace beds suggesting drag folding along the west side of the structure, and lithologic evidence where the fault is the contact between Wallace and Libby strata. Small quartz veins and green copper-staining was noted adjacent to the fault zone.

The West Pipe Creek fault is a segment of the Pipe Creek fault that splits at the mouth of Shafer Creek, continues up Pipe Creek valley, and rejoins the Pipe Creek fault near the mouth of Zulu Creek. This segment splits into two parts a mile east of Flatiron Mountain. The split extends for a distance of five miles, strikes N. 45° to 65° W. and dips south.

The West Pipe Creek fault is a normal vertical to near-vertical structure.

Skyline fault.--The Skyline fault strikes N. 30° to 40° E. from Rabbit Creek, crosses O'Brien and Kedzie Creeks, and passes east of Skyline Peak. It dips eastward. The fault zone is exposed two miles north of Pulpit Mountain in a road cut. The zone is 25 feet wide and consists of crushed and gougy material. On Skyline Mountain a 20-foot metadiorite dike, believed to be the extension of this fault, strikes N. 40° E. and dips 65° SE.

Faulting in the Wallace formation in this area (see pl. 1, sec. A-A') has cut out about 7,000 feet of argillite and dolomite limestone.

The Skyline fault displaces the axis of the Sylvanite anticline, and the southwest extension of the fault may follow Rabbit Creek. Erdmann (1945, p. 69) mapped a fault that strikes N. 50° E. in a roadcut 75 feet northwest of the Troy bridge. This fault, whose crushed zone is 10 to 15 feet wide, may be the southward extension of the Skyline fault into Libby quadrangle. Actual displacement is unknown.

East-West faults.--East-West faults have been mapped throughout the $S\frac{1}{2}$ of the Yaak quadrangle. These faults displace northwest faults and have surface traces in some places of 10 to 12 miles. The structures have moderate to high-angle dips, the north block moving up along some and down along others. Movement on these faults may not exceed 1,500 feet, the displacement in many places amounting to only a few hundred feet. The horizontal component of movement on a fault in sec. 22, T. 33 N., R. 32 W. was 250 feet, the north side having moved west. Gouge zones up to 10 feet wide occur in these faults along the Kootenai River.

Northeast faults.--Three faults in this group were mapped in the quadrangle. One fault, one-half mile west of Horse Lakes in the northeastern part of the quadrangle, strikes N. 20° E. and dips 65° NW. This fault was observed in a road cut in sec. 36, T. 34 N., R. 31 W. Another fault, in sec. 21, T. 32 N., R. 32 W., strikes N. 45° E., displaces an east-west break, and truncates the axis of the Quartz Creek syncline, the east side having moved northeast.

Northeast-striking slips in sec. 18, T. 33 N., R. 34 W. are post-fault and dike fractures. The breaks are later than the Kilbrennan fault and the dike which occupies the structure.

The Duplex vein at the Duplex property is displaced by a fault striking N. 15° E. and dipping 40° SE.

Other northeast faults undoubtedly occur throughout the area; however, detailed mapping may be required to determine their locations.

North-South faults.--From field evidence, north-trending faults appear to be the latest in the quadrangle. One fault, two miles north of the junction of Kootenai and Yaak Rivers, displaces an east-west structure, the east side having moved north. In sec. 27, T. 34 N., R. 32 W., another north-striking fault offsets an east-striking fault, and here the east side has apparently moved south.

An inferred south segment of the Quartz Creek fault may correlate with a west-dipping fault mapped by Gibson one and one-half miles west of the confluence of Quartz Creek and the Kootenai River. In both quadrangles, the fault parallels, the synclinal axis of the Quartz Creek syncline, and the downthrown block is to the east.

Age of Faults and Folds

Definite evidence for dating faults and folds is lacking in the Yaak River quadrangle. Folding occurred after the Belt sediments were deposited, and faulting has displaced fold axes throughout the area. Cambrian sediments, as fault blocks, were mapped by Gibson in the Libby quadrangle.

Kirkham (1930, p. 373) assigned a Jurassic age to the Idaho batholith, and C. P. Ross concurred that a Jurassic age was probable for this igneous body. Others have suggested a Cretaceous age for this granite mass and the Nelson batholith. The Leonia fault cuts a stock or cupola of what has been assumed an outlier of the Idaho batholith.

Folding, faulting, and igneous granitic intrusives are related to the Laramide orogeny that has been recognized by many others as occurring during late Cretaceous or early Tertiary time. Folding and faulting in the Libby and Yaak quadrangles is undoubtedly associated with this orogeny. It could have commenced as early as Jurassic time and ended during the early Tertiary period.

Relation of Faulting to Ore Deposits

In most places faults have been the controlling factor for location of dikes and sills throughout the Libby and Yaak quadrangles. Additional movement has occurred before and after igneous activity throughout the area. Reactivation of east-west faulting has occurred, and movement may have occurred in relatively recent times.

Additional movement after dike emplacement created sheared or faulted areas favorable for deposition of ore minerals. In veins cutting sediments additional movement after deposition of early quartz is evidenced by brecciated quartz and wall-rock enclosed within sulfide vein material.

SUMMARY OF FAULTING

The four major faults in the Yaak area are the Leonia, Pine Creek-O'Brien Creek, Skyline, and Pipe Creek faults. The fault with the largest displacement is the Leonia fault, a high-angle reverse type that trends northwesterly from the Libby quadrangle to near Cranbrook, British Columbia, a distance of over a hundred miles. Folding preceded all faulting in the area.

Northwest-trending faults are both reverse types (Leonia fault) and normal faults (Pine Creek-O'Brien Creek, Poole Lake, and Pipe Creek faults). Bedding faults, which were probably the earliest-formed faults, are usually small.

East-west faults displace northwest faults; fault traces extend for ten to twelve miles, and fault planes dip 40° or more. Some are vertical. East-west faults strike approximately normal to fold axis. The strike direction of these faults changes as fold axis change direction.

Northeast faults may be later than east-west structures, or nearly contemporaneous. At one location a northeast-striking fault displaces an east-west fault; at the Duplex mine a quartz vein is displaced by a north-east striking fault.

North-south faults displace east-west faults, and are the latest faults in the quadrangle.

Movement along east-west faults has occurred during recent geologic time. Fault traces displace late Pleistocene lake beds and glacial till deposits on benches and in valleys.

G E O L O G I C   H I S T O R Y

The Libby and Yaak River quadrangles are underlain by strata of the Belt series of Precambrian age. During Belt time over 40,000 feet of these sediments accumulated in the Libby-Yaak area. The series may have been deposited from 500 million to as many as 1,000 million years ago in a shallow sea or interconnected saline lakes under a climate more arid and colder than it is now.

The Belt rocks, divided into four conformable groups, are the pre-Ravalli (Prichard formation), Ravalli, Piegan (Wallace formation), and Missoula (Striped Peak and Libby formation), which are differentiated from one another on the basis of color, texture, rock composition, and metamorphism. Algae, which are one of the lowest forms of life, are the only fossiliferous remains found in Belt rocks. The algae are simple one-celled plants, grow in colonies, secrete lime, and their remains in rocks in places resemble cabbage heads. Worm trails and burrows have been found indicating a primitive form of animal life in these seas.

There were no trees or plant life on earth to slow down the forces of erosion, so material was first rapidly eroded from distant land masses and deposited in this shallow fluctuating basin. The original material, consisting of sands, muds, and clays, was obtained from a land mass to the west, probably west of Bonners Ferry and in the vicinity of Spokane and Lake Coeur d'Alene or possibly even farther west. Shallow-water deposition is evident from such features as ripple-marks and mud-cracks. Cross-bedding, clay-gall conglomerate, and casts of salt crystals are present throughout the Belt strata.

Continuous deposition of quartzites and quartzitic argillites during Prichard and Ravalli time took place during a prolonged period of gradual subsidence. During the time when lower Wallace sediments were deposited, the shoreline fluctuated as is shown by alternation of shallow-water mud-cracked, ripple-marked argillites and deeper-water limestones. Shallower-water conditions again prevailed during the time when Striped Peak sediments were deposited. Seas again advanced westward followed by a deeper-water deposition of argillites and limestones of the Libby formation without the characteristic shallow-water features. During the deposition of the Prichard and Ravalli strata, subsidence kept pace with deposition of sediments; however, during parts of Wallace time more rapid subsidence favored the deposition of limestones. Local conditions may have been responsible for such thicknesses of limestone as in the Yaak Mountain area.

Recrystallization of sands and muds to quartzites and argillites throughout the series may have been accomplished by static metamorphism through deep burial accompanied by consequent increases in temperature and pressure.

During late Precambrian or early Paleozoic time, regional uplift and slight deformation, accompanied by erosion, occurred, and the Belt sediments were intruded by diorite sills with compositions similar to the Purcell sills in British Columbia and Boundary County, Idaho.

To what extent lower Paleozoic rocks covered Belt sediments is not known. Erosion has stripped sediments so that the top of the Libby formation has been removed. No complete record of sedimentation during early Paleozoic time is available. Small blocks of Cambrian limestone, probably occurring as down-dropped fault blocks, outcrop on Clark Fork and on Swamp Creek in the Libby quadrangle.

Belt rocks were elevated and folded during the Laramide orogeny. This period of mountain-building occurred approximately 70 million years ago, and the accompanying faulting and igneous activity were mainly responsible for the formation of ore deposits. Cooling magma produced solutions that flowed through faults and sheared zones depositing vein forming minerals.

After the area was elevated erosion commenced and stream gorges developed into our present day valleys.

The land surface was again modified by the Pleistocene Cordilleran ice sheet that extended a short distance south of Libby and Troy. This ice sheet at one time may have covered most of the present land surface except for a few of the highest peaks.

Glacial Lake Missoula was formed by the damming of Clark Fork River by glacial ice that moved southward in northern Idaho. Glacial ice must have come up Kootenai Valley also. Lake Missoula extended as far south as Darby and as far east as Drummond; but northwestern Montana was covered by glacial ice. As the ice-sheet retreated northward, its melt-water created another glacial lake (Lake Kootenai) in extreme northwestern Montana. Waters of this lake may have mingled with those of Lake Missoula over the Bull Lake saddle in southern Lincoln County. However, glacial Lake Missoula must have been completely drained before glacial Lake Kootenai because the ice dam across Clark Fork must have melted before the ice retreated far enough northward to allow drainage from glacial Lake Kootenai westward. Excess melt water from glacial Lake Kootenai must have spilled over Bull Lake divide into Clark Fork drainage until ice retreated at least as far north as Bonner's Ferry, Idaho. The only evidence of the lakes existence in Montana is found in the scattered remnants of stratified glacial-lake clay and silt deposits.

Since Pleistocene time, normal erosion has been the principal geologic activity in the area, although suggestions of offsets in unconsolidated deposits and fresh fault-scarps are indications of continued readjustment along existing faults.

ORE DEPOSITS

The ore deposits of the Libby and Yaak River quadrangle occur as placer gold deposits and lode deposits. The placer deposits are relatively unimportant in point of production, having accounted for less than one percent of the value of total metals produced.

LODES

Lode deposits of the area occur along faults and fracture zones in metadiorite dikes and sills, and in sedimentary rocks of the Belt series. They constitute fissure-fillings and replacements, and the more productive veins have been found in dikes that range in width from a few feet to several hundred feet. In the south half of the Yaak River quadrangle, most of the dikes and sills are found in the Brushy Creek-Ruby Creek-Star Creek drainages. Veins in dikes contain abundant quartz that has replaced, or partly replaced wall-rock, and inclusions of wall-rock are found in the veins. The lode deposits can be further classified as:

1. Gold-quartz veins
2. Silver-lead-zinc veins
3. Copper veins
4. Barite veins

Gold-Quartz Veins

Gold-quartz veins occur in the Fisher River (Cabinet) district, Libby Creek (Snowshoe) district, at Sylvanite and the Black Diamond mine, and southwest of the Leonia fault in the Ruby Creek-Star Creek drainages.

In the Libby and Yaak areas native gold occurs in quartz veins or is associated with quartz and sparse sulfides. In the veins a white massive quartz makes up the major part of the vein material. Gold commonly replaces quartz grains and occurs as irregular masses or small elongated particles. Other ore minerals associated with the gold-bearing quartz are pyrite, pyrrhotite, sphalerite, galena, and chalcopyrite. Gangue minerals are sericite, chlorite, calcite, dolomite, and magnetite. Quartz, pyrite, and pyrrhotite were deposited early in the above-named sequence, followed by sphalerite, galena, and chalcopyrite. Gold replaces quartz and is sometimes closely associated with sphalerite. Coarse native gold visible to the naked eye has been reported in ores from the Fisher Creek, Golden West, Midas, and Tip Top mines. Gold is found as small masses or between contacts of grains of quartz and base metals.

At Sylvanite quartz vein range from 2 to 50 feet wide. Narrow veins may follow bedding planes of Prichard argillite and quartzite. This formation forms the core of Sylvanite anticline. Veins and veinlets in shear zone at the Black Diamond mine, near a basic ingeous intrusive, contain native gold.

Silver-Lead-Zinc Veins

Silver-lead-zinc veins are found in the Troy (Grouse Mountain, Callahan) district, the Libby (Snowshoe) district, in the Blue Creek fault area, and near the Glacier mine on Shaughnessy Creek.

These veins in the two quadrangles occur in Prichard, Ravalli, and Wallace strata of the Belt series, or in metadiorite dikes; a few are found in basic sills. The veins generally strike in a northwest direction and dip at high angles to the east and west. They range from a few inches to 12 feet wide. The veins have filled fault fissures, contain brecciated quartz and country rock, and in some places post-mineral faulting occurs along the vein.

Ore minerals consists of argentiferous galena, sphalerite, and minor amounts of native gold. Other common minerals are pyrite, pyrrhotite, chalcopyrite, arsenopyrite, magnetite, and scheelite. Gangue minerals include quartz, calcite, sericite, chlorite, and iron oxides.

Wall rock alteration is weak; only sparse amounts of sericite and chlorite are usually present in the vein material. For a few inches adjacent to some veins quartzite wall rock has been recrystallized; however, recrystallization is an exception and not the rule.

Copper Veins

In the Libby and Yaak River quadrangles copper prospects occur along Rock Lake fault, on Copper Mountain, near Stanley Peak and Mount Vernon, at Cedar Creek and Copper Gulch, and one deposit occurs about seven miles north of Libby on Pipe Creek.

Copper mineralization generally occurs in quartz veins, some of which are as much as 30 feet wide. Chalcopyrite is the dominant copper mineral, although bornite, chalcocite, tenorite, azurite, and malachite are present in small quantities. Gangue minerals are quartz, calcite, and pyrite.

Copper veins strike from northwest to northeast, to easterly in Prichard, Ravalli, and Wallace host rock. Mineralization is spotty and sparse. The tenor of many copper veins ranges from 0.10 to several percent copper, contain up to about 0.10 ounces of gold and from 5 to 25 ounces of silver to the ton.

Copper deposits have not been productive to date.

Barite Veins

Only one occurrence of barite in veins is so far known within the area. This occurrence is on the Kotschevar claims in secs. 1 and 12, T. 30 N., R. 34 W., in the Troy district. Here, barite is associated with ankerite and siderite in veins cutting Wallace strata. The deposits are more fully described under the heading "Kotschevar" on page 44.

HISTORY AND PRODUCTION

Schrader (1911, p. 70) stated that prospecting was being carried on in the Libby district as early as 1867. During this period several prospectors were killed by hostile Indians. Mr. Bert Tallmadge, a long-time resident of the Bull Lake area, visited a cabin site near Bull Lake in 1890 that he believed had been erected twenty or thirty years previous to his visit. Trees, several inches in diameter, were growing within the walls of the abandoned cabin.

Gibson (1948, p. 25) believed prospectors from the Coeur d' Alene district commenced prospecting in the Libby region in the early eighties. Most early mining activity was on placer claims located on Libby, Cherry, and Callahan Creeks. Placers were also located on the Kootenai River near the present site of Troy. Production from the Troy placers was evidently negligible.

The Snowshoe mine was found by John Abbot in 1889, the Sylvanite mines were were active in 1898, and many other properties were located between 1890 and 1900. During 1903-1904 Calkins (1909, p. 99-105) visited the Big Eight and the Snowstrom (formerly the B & B) mines in the Troy district, and the Snowshoe and Silver Butte mines south of Libby. At this time the Sylvanite properties were idle and the town of Sylvanite deserted.

Construction of the Great Northern Railroad in 1890 stimulated mining and lumbering thoughout the district; however, after 1900 lumbering replaced mining as the more important industry in the Yaak-Troy-Libby area.

The table on page 33 summarizes by decades the production of gold, silver. copper, lead, and zinc in Lincoln County from 1901 through 1957. The figures prior to 1937 are from Gibson (1948, p. 70), but have been brought up to date from published data in annual volumes of the Minerals Yearbook, issued by the U. S. Bureau of Mines.

Production is divided between the Libby (Snowshoe) district, the Troy (Callahan Creek) district, and the Sylvanite district. The gold production of the West Fisher River (Cabinet district) mines is included under the Libby district. All mines in the Yaak River quadrangle are included in the Sylvanite district figures. The table indicates that mining in the Yaak River quadrangle has been very sporadic. The principal production has come from the Black Diamond mine (last operated in 1939) and the properties now under control of the Morning Glory Mines, Inc. The Morning Glory properties ceased production in 1940. Since that time reported production has come from outlying mines near Leonia and the Ruby Creek area southeast of Leonia.

At present there is considerable activity in prospecting and development, but no production has been reported from Yaak River quadrangle since 1951 except for a very small amount of gold, silver, and lead in 1957, the total value of which was but $740.00.

DESCRIPTION OF MINING PROPERTIES, YAAK QUADRANGLE

New Morning Glory

The Morning Glory mine, located near Sylvanite in secs. 16 and 17, T. 34 N., R. 33 W., has consolidated properties formerly known as the Morning Glory, Keystone, and Goldflint that MacDonald (1909, p. 102) reported were on the same vein. The property is presently being developed by a Coeur d' Alene mining company.

Underground and surface installations consist of two accessible adits, one inaccessible incline shaft and adit, an abandoned stamp mill, and several collapsed buildings.

From 1931 to 1937, production from the Sylvanite mines amounted to slightly over 22,200 tons of ore valued at $246,000. It was reported the Thornton brothers operated the property during this period, and production was 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; however, production figures for this period are not available.

Production of Gold, Silver, Copper, Lead, and Zinc in Lincoln County, Montana, 1901-1957

(Compiled from U.S.G.S. Bull 956 and U.S.B.M. Minerals Yearbooks, v. 1938 thru 1957.)

District	Period	Ore (Tons)	Gold (Oz.)	Silver (Oz.)	Copper (Lb.)	Lead (Lb.)	Zinc (Lb.)	Total Value
Libby (Snowshoe, Cabinet)	1901-1910	71,158	3,427	117,170	279	5,833,551	---	$ 358,278
	1911-1920	14,825	2,806	40,618	---	1,987,944	---	171,137
	1921-1930	37,531	2,118	69,047	466	1,200,558	26,186	172,648
	1931-1940	32,517	6,115	35,237	2,877	374,842	---	220,705
	1941-1950	39,845	3,000	20,379	5,350	629,200	335,400	201,922
	1951-1957	85	45	---	---	---	---	1,575
	Totals	195,961	17,511	282,451	8,972	10,026,095	361,586	$1,126,265
Troy (Callahan Creek, Grouse Mtn.)	1901-1910	---	---	---	---	---	---	---
	1911-1920	219,942	2,055	514,178	108,770	20,806,061	4,934,886	$2,478,634
	1921-1930	148,482	754	198,063	15,571	8,494,965	1,819,887	864,227
	1931-1940	2,108	36	4,007	15,965	216,863	236,801	26,921
	1941-1950	523	12	1,146	600	75,700	76,000	15,877
	1951-1957	---	---	---	---	---	---	---
	Totals	371,055	2,857	717,394	140,906	29,593,595	7,067,580	$3,385,659
Sylvanite (Yaak) [Includes: Warland (1949) Ruby Creek (1949,1951)]	1901-1910	175	55	556	---	6,423	---	$ 1,718
	1911-1920	---	---	---	---	---	---	---
	1921-1930	12	19	42	---	2,040	---	551
	1931-1940	61,421	10,824	47,907	20,431	412,309	---	428,448
	1941-1950	277	52	905	600	43,600	14,600	9,527
	1951-1957	96	9	207	---	9,400	6,000	3,160
	Totals	61,901	10,959	49,617	21,031	473,772	20,600	$ 443,404
County Totals		628,997	31,327	1,049,462	170,909	40,093,462	7,449,766	$4,955,328

The country rock is Prichard quartzite and argillite that strikes N. 20° W. and dips 30° NE. and contains some sandy and shaly horizons. The beds range from white and grey quartzite to a dark- to light-grey thin- to medium-bedded shaly argillite.

MacDonald (1909, p. 103) reported production from a one- to two-foot quartz vein dipping 30° E., paralleling the bedding of argillite and quartzite. At the time of his visit the operators were mining auriferous pyrite and native gold. Metadiorite dikes are present in the area.

Two near-vertical quartz veins, striking N. 40° W., outcrop 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, from 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 inaccessible shaft 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. A narrow vein was productive at an early date; however, 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 the upper adit assayed 0.64 ounces of gold and 3.20 ounces of silver a ton.

A program, currently in the charge of Clyde Thornton, is reported to be developing lead-zinc ore at depth on the property.

Duplex

The Duplex property is near the center of sec. 29, T. 33 N., R. 34 W. There are five unpatented claims owned by A. M. Bartlett, who operated a cafe on U. S. Highway 2 at the Montana line.

Recent production from pillars amounted to 100 tons of ore shipped to East Helena. Net value of ore from smelter returns was $36.00 a ton. Bartlett stated that one heading produced ore assaying $112.00 a ton, and considerable stoping in an upper adit was done prior to acquisition by Mr. Bartlett.

Development consists of two adits and a 20-foot winze. The adits are accessible but hazardous. The winze encountered water that hampered sinking operations.

The vein occurs in a metadiorite sill between sedimentary beds of Prichard formation. More detailed field work may be necessary to determine the relationship of the igneous body and country rock. Kirkham, Ellis, and Erdmann have mapped igneous structures on the Idaho side as sills.

The vein, trending diagonally across the sill, ranges from $3\frac{1}{2}$ to 5 feet wide, and near the portal of the adit strikes N. 70° E. and dips 70° SW. At the portal, the vein is displaced by a fault striking N. 15° E. and dipping 40° SE. Along the fault is a zone one-foot wide containing fragments of brecciated country rock and gouge. The offset segment of the vein has not been located.

Ore minerals are galena, sphalerite, chalcopyrite, and pyrite, with a little gold and silver. Gangue minerals are quartz and calcite.

Oro

The Oro property, in the $S\frac{1}{2}$ sec. 36, T. 32 N., R. 35 W., was discovered in 1935 during logging operations in the Ruby Creek drainage and was subsequently staked by Messrs. Ronald and Norman Obermayer. In 1947 the property was leased by the Bunker Hill Company of Kellogg, Idaho. Later the property was acquired by the Inspiration Lead who did considerable development work. The ground has been recently restaked by W. G. Dailey and L. R. Rittenhouse.

The vein is developed by a 600-foot accessible adit and an inaccessible upper adit. 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 the Callahan Creek.

The ore consists of galena, anglesite, chalcopyrite, pyrite, and quartz. A stockpile of vuggy material containing abundant iron oxides and quartz assayed 5.10 percent lead, 0.40 ounces silver, a trace of gold, copper, zinc, and 3.30 percent iron. Some ore was reported shipped to the Bunker Hill smelter.

Mr. 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, in the $NW\frac{1}{4}$ sec. 2, T. 33 N., R. 34 W., was relocated by W. A. Rankin of Troy in 1958. The Pine Creek valley property has been idle since 1941. Prior to this time, the mine was developed and financed by Charles Cone and other interested Troy and Libby residents. The property was discovered in the early twenties. Shortly thereafter a shipment of lead-gold ore was sent to a smelter for testing. The property consists of three unpatented claims.

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 the fracture zone on a hillside.

A 100-ton mill, erected in 1936, operated intermittently until 1947. Prior to 1958 the mill was partially torn down and the machinery removed.

Native gold is associated with quartz and some galena, pyrite, sphalerite, chalcopyrite, and pyrrhotite. Quartz veins and veinlets occur in a fracture zone in Ravalli quartzite. Veins are from a few inches to about two feet wide, whereas the veinlets in the fracture zone are from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick. The quartz veins and veinlets strike in a north to northeasterly direction and dip east and southeast. Veins are usually steep to vertical. W. A. Rankin reported selected specimens assayed 3 ounces of gold a ton. The fracture zone and adjacent quartz veins are a short distance east of the Pine Creek-O'Brien Creek fault. A metadiorite dike lies adjacent to or within this fault zone.

State Line

The State Line prospect lies approximately 1,000 feet southwest of 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 strikes N. 50° W. and dips 65° NE. The dike encloses two small quartz veins. One vein, 3 to 5 inches wide, parallels the strike of the dike. Another vertical vein, about 3 inches wide, cross-cuts the dike. The dike is in a dark- to medium-grey argillaceous quartzite of the Prichard formation. Wall rock alteration is weak at the dike contact, although Prichard quartzite has been weakly recrystallized and some silicification was noted. Sericitization is weak to absent. Mineralization has resulted in white to grey massive quartz veins containing pyrite, limonite, hematite, and possibly some gold; however, no gold was visible in hand specimens. Some quartz monzonite float was found in the vicinity; it may be of glacial origin.

Yaak Falls

The Yaak Falls prospect is in the SW$\frac{1}{4}$ sec. 4, T. 33 N., R. 33 W., approximately 100 feet west of the Yaak road at Yaak Falls. The vein is in dark to grey quartzite and quartzitic argillite of the Ravalli group.

The prospect is developed by an adit for a distance of 150 feet along the strike of the vein. The adit is accessible. Several veinlets of quartz and galena, from a fraction of an inch to an inch wide, cross the Yaak River near the falls.

A 10-inch quartz vein strikes east-west and dips 60° S. Minerals include white and grey massive quartz with iron and manganese oxides. A channel sample of the vein near the portal assayed a trace of gold, lead, zinc, and 0.30 ounces of silver and 0.04 percent copper.

Rankin

The Rankin prospect is in sec. 14, T. 32 N., R. 34 W. The prospect is developed by a 6-foot pit in grey dolomitic limestone and calcareous argillite of the Wallace formation. Wallace beds strike N. 10° W. and dip 80° NE.

Several quartz veinlets, from $\frac{1}{4}$ to 3 inches wide, parallel the bedding of the sediments. A metadiorite dike was mapped a short distance west of the pit and a stock-like mass of metadiorite outcrops southwest of the prospect.

An assay of dump material contained a trace of gold and 0.10 ounces of silver a ton.

McEwen

The McEwen prospect is 7 miles above Libby in the Pipe Creek drainage. Mineralized matter consists of pyrite, chalcopyrite, iron oxides, and quartz. Selected specimens assayed 1.06 percent copper and 0.10 ounces of silver a ton.

Ferrel

The Ferrel prospect is in the NE$\frac{1}{4}$ sec. 9, T. 33 N., R.33 W. An inaccessible adit lies about $\frac{1}{4}$ mile west of Yaak road. A dark-grey argillite containing pyrite veins occurs on the mine dump. The pyrite was formed when the sediments were deposited. Selected dump specimens assayed a trace of gold, silver, and the base metals.

Other Prospects

An inaccessible adit on a quartz vein striking east-west (?) is at the mouth of Kilbrennan Creek. Several prospects also occur in the Ferrel Creek drainage.

Snipetown Placer

The Snipetown placer is on a bend of the Yaak River below Yaak Falls in the center of sec. 19, T. 33 N., R. 33 W. 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 $0.90 to $3.00 a cubic yard in a pay streak found in clay above bedrock. Some fine flake gold and 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 at the river bend in Ravalli quartzitic argillite. Higher terraces may have gold-bearing gravel, although placering was confined to the lower bench.

No records of production are available.

China Lake Placer

It has been reported that placers yielded some gold from China Creek and in the vicinity of China Lake during early placer mining operations in the Libby area. No evidence of placering in the vicinity now remains.

NONMETALLIC DEPOSITS

Vermiculite

The largest vermiculite mine in the United States has been developed by the Zonolite Company in the Rainy Creek district 7 miles northeast of Libby. The deposit was discovered in 1915, and small-scale production started in 1925. In 1939, the several different operations were combined into one under the Universal Zonolite and Insulation Company, the name of which was changed to the Zonolite Company in 1948. A 1,000-ton mill, erected in 1948, produced 350 to 400 tons of concentrate per day, and it is presently being enlarged. Although the company has an expanding plant in Libby, the bulk of the concentrate is shipped as crude vermiculite to expanding plants throughout the country. The expanded vermiculite is marketed under the trade-name, Zonolite.

The deposit is an elongated stock composed of pyroxenite and syenite. The stock intrudes strata of both the Wallace and Striped Peak formations in the trough of a northwest-trending syncline. The pyroxenite is very coarse-grained and composed of vermiculite, aegerine-augite, soft fibrous amphibole asbestos (tremolite), magnetite, and locally a little biotite. Fluorine-rich apatite makes up 7 to 10 percent of the rock. The vermiculite has been derived from biotite by hydrothermal alteration, and locally, the quality of the vermiculite probably has been enhanced by weathering. The fibrous amphibole is an alteration product of the aegerine-augite, and the stages of alteration can be seen megascopically in hand specimens. The aegerine-augite is locally vanadiferous (Pardee and Larsen, 1929, p. 17).

The pyroxenite is cut by syenite dikes ranging in width from a few inches to many tens of feet. The dikes are composed of orthoclase, sodic plagioclase, and a little muscovite. Accessory minerals are hornblende, fluorite, apatite, titanite, rutile, biotite, and garnet (Pardee and Larsen, 1929, p. 21).

Quartz veins in the stock are later than the syenite and contain small amounts of chalcopyrite, sphalerite, and galena.

This unusual stock has many minerals of potential value. The vermiculite, of course, is being actively marketed at present. Fibrous amphibole asbestos, because its specific gravity is very near that of vermiculite, causes much trouble in milling the lower grade ores in which the asbestos is abundant. If a process could be perfected to make a clean separation of vermiculite and asbestos, both products would be marketable, and much material now mined and dumped as waste could be milled and made to yield a profit.

Much of the syenite is nearly pure feldspar. Dikes which occur within the pyroxenite ore-body must be mined along with the vermiculite rock. At present the syenite is dumped as waste. It is said that minute inclusions of hornblende in the feldspar render the feldspar unsuitable for ceramic use. Perhaps it could be used as a flux in glass manufacture, or ground to a scouring powder of the Bon Ami class. (The basic ingredient of such powders is ground feldspar.)

The border phase of the pyroxenite intrusive where it comes in contact with Belt sediments is magnetite-rich. A grab sample of the material showed about 16 percent magnetite. An analysis of a magnetic concentrate from this material gave 63.80 percent iron, 0.60 percent titanium dioxide, 2.40 percent silica, and 0.50 percent phosphorus; also, a trace of sulfur. The high phosphorus was probably due to the presence of fluorapatite in the pyroxenite.

The quartz veins of the pyroxenite area, according to Pardee and Larsen (1929, p. 27), contain a variety of minerals, chiefly quartz with scattered grains of galena and chalcopyrite. Along the walls of one vein are zones a few inches wide made up chiefly of vanadium-bearing aegirite, microcline, strontianite, celestite, pyrite, and chalcopyrite, with smaller amounts of quartz, fluorite, galena, and sphalerite. Quartz veins are ignored in mining vermiculite as they are of mineralogical interest only.

Esther May Asbestos

The Esther May claims were staked by Romeo and Virginia Garrison in 1946 and are about one-half mile west of Yaak, in sec. 34, T. 36 N., R. 32 W. The group comprises two unpatented claims, the Esther May Nos. 1 and 2. In 1948 the claims were leased to Messrs. Hough and Loveland of Spokane, Washington, for a period of ten years. The lessees drilled twelve to fifteen holes near a small asbestos vein outcropping on a bluff. All holes were reported to have intercepted amphibole asbestos at depths of twenty to thirty feet. In 1958, Messrs. H. P. Reinshagen, Sr. and Jr., of Libby, Montana, leased, with option to buy, the property for a period of one year. A diamond drill program is planned to check previous churn drill results.

A vertical vein of tremolite and anthophyllite asbestos, about 3 inches wide, is exposed at the base of a bluff. It trends N. 10° W. Wallace country rock strikes parallel to the vein and dips 75° NE. A second vein, 6 inches wide, has been recently exposed in a shallow pit where the vein strikes N. 70° W. and dips 60° SW. It has been reported that autunite, a uranium-bearing mineral, was found associated with a 3-inch syenite dikelet in a small pit at the face of the bluff. The dike strikes N. 70° E. and dips 70° SE. The Wallace argillite has been hydrothermally altered, and silica introduced into the surrounding country rock. A metadiorite body, whose trend was not determined also outcrops in the area. Development work consists of two small surface pits, one on the 6-inch amphibole asbestos vein, and the other on the syenite dike.

Larue-Cripe Asbestos

Messrs. Donald Cripe and Dave Larue have recently staked four claims on a tremolite asbestos vein in the Wallace formation, one and one-half miles southwest of Roderick Butte. The property lies in sec. 26, T. 35 N., R. 32 W.

The vein ranges from 3 to 6 inches wide, strikes N. 70° E. and dips 55° NW. Tremolite asbestos is exposed in two small surface pits. Wallace argillite strikes north and dips 55° E. The argillite has well-developed ripple-marks and mud-cracks.

Virginia Garrison Clay Deposit

Mrs. Virginia Garrison has one claim on a clay deposit two miles southeast of Yaak, Montana, on a tributary of the Yaak River north of Heat Creek. The clay deposit is a remnant of a glacial lake deposit. Samples of the clay assayed from 20.60 to 25.20 percent alumina and a trace of gold and silver.

Limestone and Quartzite

Limestone and dolomitic limestone of the Wallace formation contain large amounts of silica, moderate amounts of alumina, and iron. Samples with high carbonate content and small amounts of other constituents are the calcareous tuffa deposits outcropping near the Jack Garrison ranch in the Libby quadrangle, on the east Pipe Creek road, and on the D. A. Sheffler ranch near Leonia. The purest limestone found was a high-magnesian limestone in the Libby formation, east of Libby Creek bridge on U. S. Highway 2. Most of the calcareous rocks of the Belt series are too impure to be considered possible sources of commercial limes.

Analyses of limestone beds sampled are given in the Appendix to this report.

Quartzite beds from a few inches to 15 or 20 feet thick occur in Prichard and Ravalli strata. They are white to grey hard crystalline quartzites that usually carry small amounts of pyrite, pyrrhotite, or biotite. Samples of the better-grade quartzites ranged from 75.5

to 82.2 percent silica and 1.5 to 2.2 percent iron. Analyses for those sampled are given in the Appendix.

DESCRIPTION OF MINES AND PROSPECTS, LIBBY QUADRANGLE

The following descriptions of mining properties in the Libby quadrangle (except for the Snowstorm mine) includes only those mines and prospects that have been active or have been located since Gibson made his survey of the quadrangle. For a description of other mines of the area, the reader is referred to Gibson (1948).

Snowshoe

The Snowshoe mine is on the south side of Snowshoe Creek in T. 28 N., R. 31 W. The property has four patented claims located in 1889 by A. F. Dunlap and J. Abbott. The claims are the Snowshoe, Rustler, Porcupine, and Chinnook (see pl. 5). Other partners in the enterprise at that time were B. Parmenter and H. G. Lougee. In 1900 an English syndicate acquired the property and commenced an extensive development program. In 1911 the mine was acquired by W. Jennison and produced thereafter for a short period. Messrs. C. H. Foot, G. H. Grubb, and H. Keith bought the property in 1940. Later the Snowshoe was leased to Messrs. B. Sharp and T. Grow who installed a portable selective flotation concentrator that milled developed ore, mine dumps, and tailings. The mill treated 500 tons per day, and several thousand tons were milled from 1940 to 1942. It has been reported that the lessees produced concentrates valued at $125,000 during a five-year period.

The property is now operated by the St. Paul Lead Company, Inc., in partnership with Merger Mines of Idaho. The St. Paul Lead Company has leased two other groups of claims: the St. Paul group from W. Zollers of Libby, and the Seattle group. Mr. A. L. Osborn, in charge of operations, reported the companies have spent $37,000 for mill construction, road building, and retimbering adits. A 100-ton flotation mill, presently nearing completion, will treat a limited amount of custom ore.

The Snowshoe vein occupies a fissured and sheared zone in the vertical Snowshoe fault. The fault trends N. 12° W. Thick-bedded calcareous shale and white limestone of the Wallace formation strike N. 30° W. and dip westerly on the west side of the fault. East of the fault the Ravalli beds are a dark-blue-grey sandstone and sandy argillite that strike N. 30° W. and dip to the east.

The sheared zone ranges from 6 to 12 feet wide and encloses quartz veins that range from a fraction of an inch to a foot wide.

Galena, sphalerite, and pyrite are the most abundant sulfides; some chalcopyrite, pyrrhotite, and arsenopyrite occur with the galena and sphalerite. Small veinlets and stringers of sulfides intermixed with quartz parallel the direction of the fracture zones. Movement took place after deposition of early quartz. Brecciated quartz fragments are enclosed by masses of sulfides. Movement after deposition of sulfides formed gouge and breccia zones in the vein.

Development work totals 11,000 feet of adits, drifts, and intermediate levels (see pl. 5). Three adits on the vein are above the hoist level; other drifts below the hoist level follow the fracture zone in a southerly direction from Snowshoe Creek. The hoist level is at an elevation of 4,729 feet.

Gibson (1948, p. 111) reports a total output of 130,000 tons of ore valued at $1,086,000. In 1934 ore reserves were 110,000 tons of developed and probable ore. The value of ore produced from the Snowshoe prior to 1906 was reported to be $850,000.

The present management states that production will commence when metal prices are more favorable.

Big Sky

The Big Sky, formerly the Montana Silver Lead, lies on the north slope of Leigh Creek on the Snowshoe fault. Big Sky Nos. 1 and 2 were relocated by Blaze Echo, Clive Roard, and Mrs. Inis Herrig in 1955. The following year the claims were leased to a Canadian syndicate for a period of 18 months.

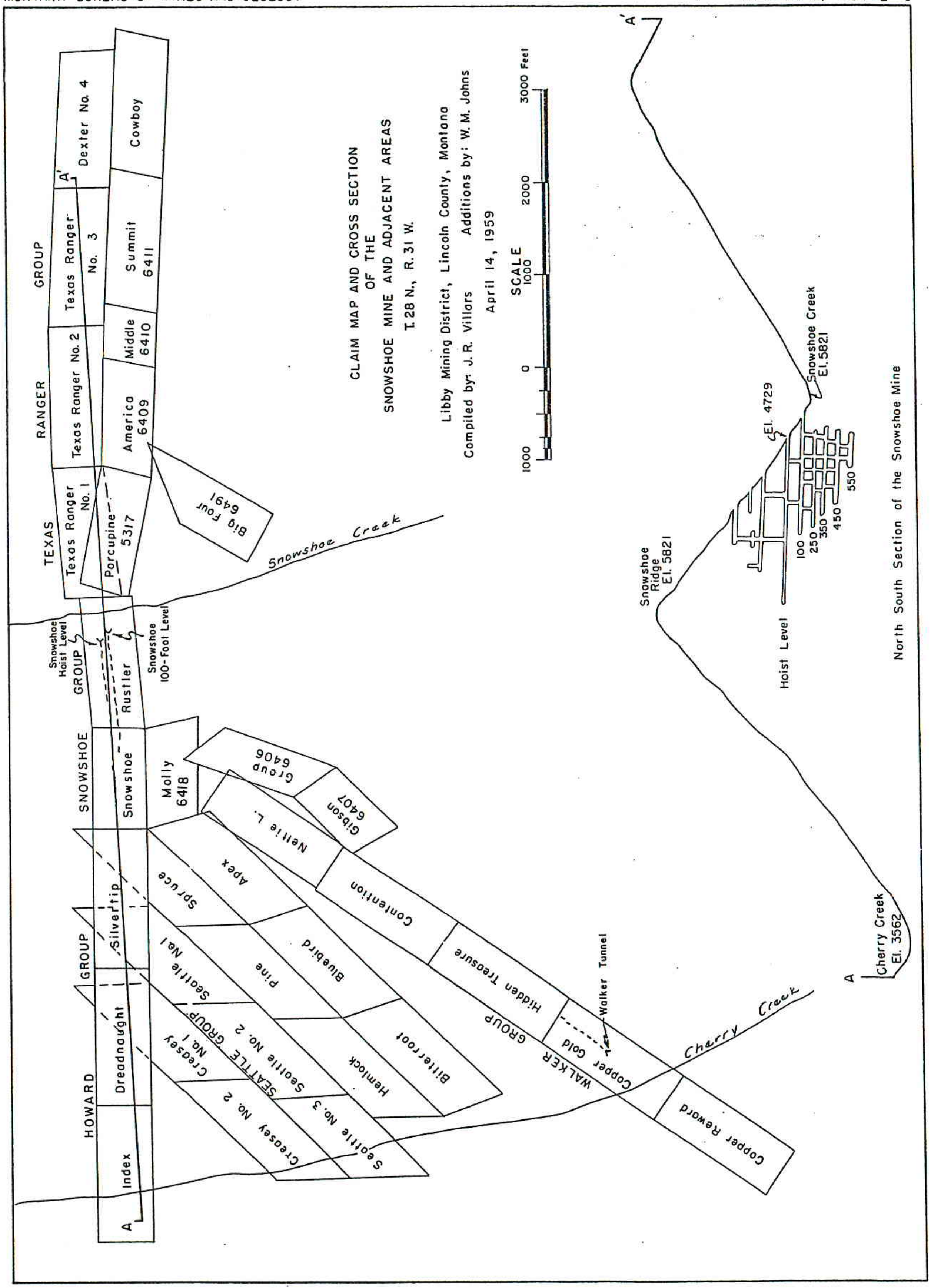
Development work amounts to 1,500 feet of workings. The lower adit is 1,000 feet and the upper adit about 500 feet long. All are accessible.

The Snowshoe fault in this locality is vertical and strikes in a northerly direction. A grey calcareous shale and brown-red limestone of the Wallace formation lie west of the fault in the downthrown block, whereas the east upthrown block is a grey argillite, white quartzite, and calcareous sandstone of the Ravalli formation. The Wallace beds are vertical, and Ravalli horizons strike N. 25° W. and dip 55° NE.

Quartz veins containing pyrite, galena, sphalerite, with minor amounts of chalcopyrite, arsenopyrite, and pyrrhotite occupy the fault, and disseminations of sulfides extend into both walls of the fault zone. Small amounts of anglesite, cerrusite, and limonite are present in the oxidized parts of the vein. Some scheelite was reported in the lower adit. The Canadian company leased the property on showings of scheelite in the adits.

Grizzly

The Grizzly claims, formerly the Missouri group, were relocated by Blaze Echo, and Mrs. Inis Herrig in 1955. The property is on Leigh Creek about 2 miles above the confluence of Leigh and Cherry Creeks. Two unpatented claims, Grizzly Nos. 1 and 3, were located one and one-half miles east of the Snowshoe fault and north of Leigh Creek.


CLAIM MAP AND CROSS SECTION
OF THE
SNOWSHOE MINE AND ADJACENT AREAS
T. 28 N., R. 31 W.
Libby Mining District, Lincoln County, Montana
Compiled by: J. R. Villars Additions by: W. M. Johns
April 14, 1959
SCALE
1000 0 1000 2000 3000 Feet
TEXAS RANGER GROUP
Texas Ranger
Texas Ranger No. 1
Texas Ranger No. 2
Texas Ranger No. 3
Dexter No. 4
Cowboy
Summit 6411
Middle 6410
America 6409
Porcupine 5317
Big Four 6491
Snowshoe Creek
Snowshoe Hoist Level
Snowshoe 100-Foot Level
SNOWSHOE GROUP
Rustler
Snowshoe
Molly 6418
Group 6406
Gibson 6407
Nellie L.
Apex
Spruce
Contention
Bluebird
Pine
Seattle No. 1
Hidden Treasure
HOWARD GROUP
Silvertip
Dreadnaught
Index
SEATTLE GROUP
Seattle No. 2
Creasey No. 1
Creasey No. 2
Seattle No. 3
Hemlock
Bitterroot
WALKER GROUP
Walker Tunnel
Copper Gold
Copper Reward
Cherry Creek
A
A'
Snowshoe Creek El. 5821
El. 4729
Snowshoe Ridge El. 5821
Hoist Level
100
250
350
450
550
Cherry Creek El. 3562
North South Section of the Snowshoe Mine

No production has been reported, and to the writer's knowledge, no ore has been mined from the property.

The property has been developed by three short adits: one 70 feet, one 40 feet, and the other 30 feet long.

Quartz veins and veinlets occupy a shear zone in Ravalli quartzite. The zone trends northwesterly and dips steeply east. Ravalli strata strike N. 10° to 30° W. and dip 30° to 45° E.

Sulfide vein minerals are galena, chalcopyrite, arsenopyrite, and pyrite. Anglesite and limonite are found in the oxidized parts of the vein, and gangue minerals include quartz, ankerite, and calcite.

Fisher Creek

The Fisher Creek mine is in sec. 12, T. 26 N., R. 31 W. on Bramlet Creek, a tributary of West Fisher River. Eight patented claims comprise the group formerly known as the Brannigan mine (see pl. 8A). The property is owned by the Fisher Creek Mining Company and produced for short periods in 1941 and 1950. The mine produced considerable ore from 1901 to 1903.

Discontinuous gentle-dipping quartz veins follow bedding planes in Prichard beds and range from 1 to 4 feet wide. Veins are irregular and lens-like. Impregnations of disseminated sulfides are found in wall-rock adjacent to veins. Prichard strata are nearly horizontal in some sections of the area, whereas the general strikes of the beds is N. 30° to 40° W. and dips 18° to 35° E. Visible native gold has been reported from some stopes.

Gold-bearing quartz veins, and others with sulfides and quartz containing sparse to moderate amounts of pyrite, galena, sphalerite, chalcopyrite, and pyrrhotite, are near fracture zones. Better ore was mined in the oxidized parts of the veins. Disseminated bunches and masses of sulfides are concentrated in some sections of the veins. Gangue minerals present in the flat-lying veins are quartz and sericite.

Veins were developed and stoped from five closely-spaced adits (see pl. 6A). The veins have been faulted by northerly-trending fissures dipping west. Vertical displacement on these faults generally does not exceed a few feet with the downthrown side on the east.

Gibson reports a specimen of oxidized ore assayed 1.66 ounces of gold and 1.44 ounces of silver a ton.

Snowstorm

The Snowstorm mine, in secs. 19 and 20, T. 31 N., R. 34 W., in the Troy district has six patented and sixty unpatented claims on and near the Snowstorm dike. The property was operated by the

Snowstorm Mines Consolidated Company from 1918 to the late twenties. In 1931 the property was controlled by the Troy Mines Company, and in recent years was owned W. A. McCaffery of Chicago, Illinois. The mine is held by the McCaffery estate, and has been inactive for the past twenty or twenty-five years.

A 350-ton mill was constructed in 1917. It milled ore from the Snowstorm mine and custom ore from the district. At one time the mine employed from 250 to 300 men. From 1918 to 1926, the greatest productive period, the Snowstorm property produced about 202,000 tons of ore valued at $1,516,000. In May 1927, the mill burned, and production since that date has been negligible.

Gibson (1948, p. 97) states, "The mine is said to have produced in all, at least $4,000,000 in lead, zinc, gold, and silver. Developed ore reserves in 1931 (including probable ore) were said to be 207,000 tons, but much of this was in the inaccessible parts of the mine above the sixth level."

The country rock is a banded grey-blue argillite and grey fine-grained sericitic sandstone and quartzite of the Prichard formation that strikes in a northwesterly direction and dips east in this locality. The veins occur in a coarse-grained diorite dike. Some veins have been stoped to a width of 10 feet. They strike N. 25° to 30° W. and dip 75° to 80° SW. The average width is about 6 to 8 feet. The Leonia fault lies a short distance east of the property.

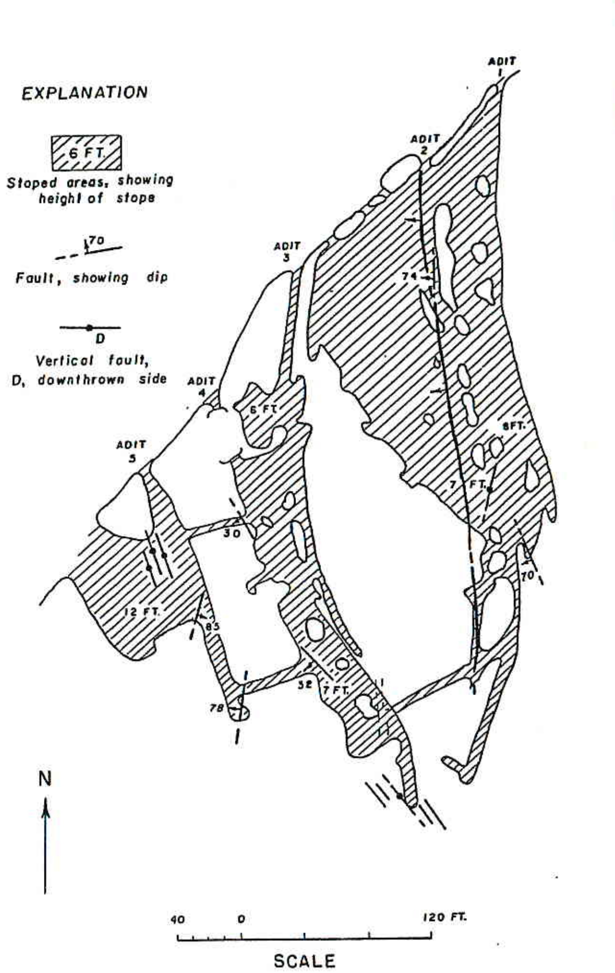
The vein minerals are galena, sphalerite, pyrite, pyrrhotite, chalcopyrite, and arsenopyrite occurring in a gangue of quartz, calcite, chlorite, amphibole, garnet, and biotite. Biotite, sericite, pyrite, and pyrrhotite have been introduced into the adjacent wallrock. Veins occur in the dike and along its contact with the country rock (see pl. 6B). It has also been reported that the gold and silver in the ore payed for milling expenses. Sections of the vein contain sparse amounts of sulfides or consist entirely of gangue minerals. Barren sections of the vein were left as pillars.

Several faults striking in a northwest direction and paralleling the Leonia fault, contain from a few inches to 2 feet of gouge and breccia. These faults dip east and west. The property is developed by several adits; no. 6 and 7 adits are 1,900 and 2,350 feet in length respectively, some of which are still accessible.

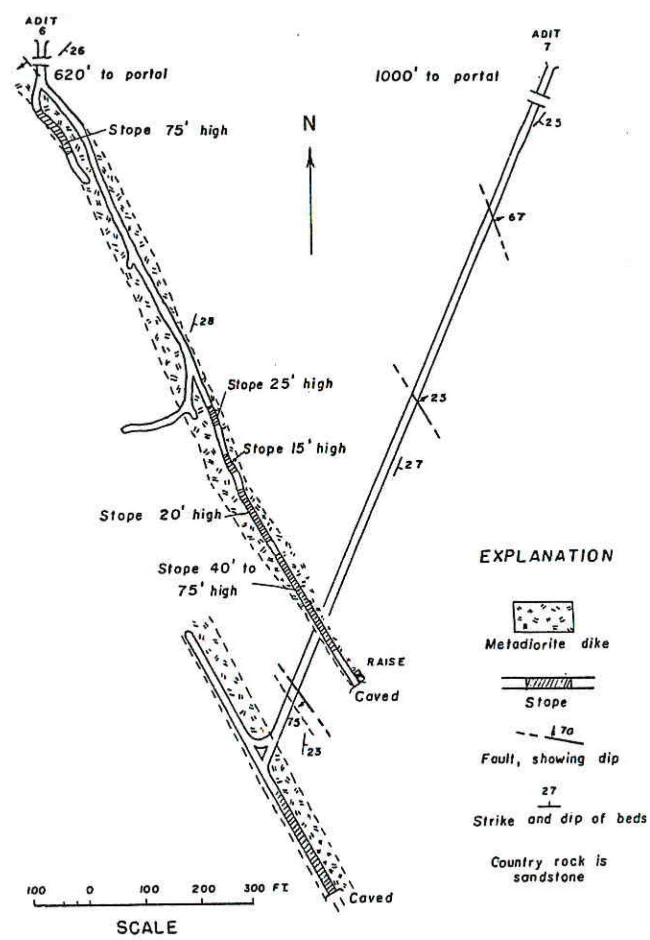
Kotschevar Barite

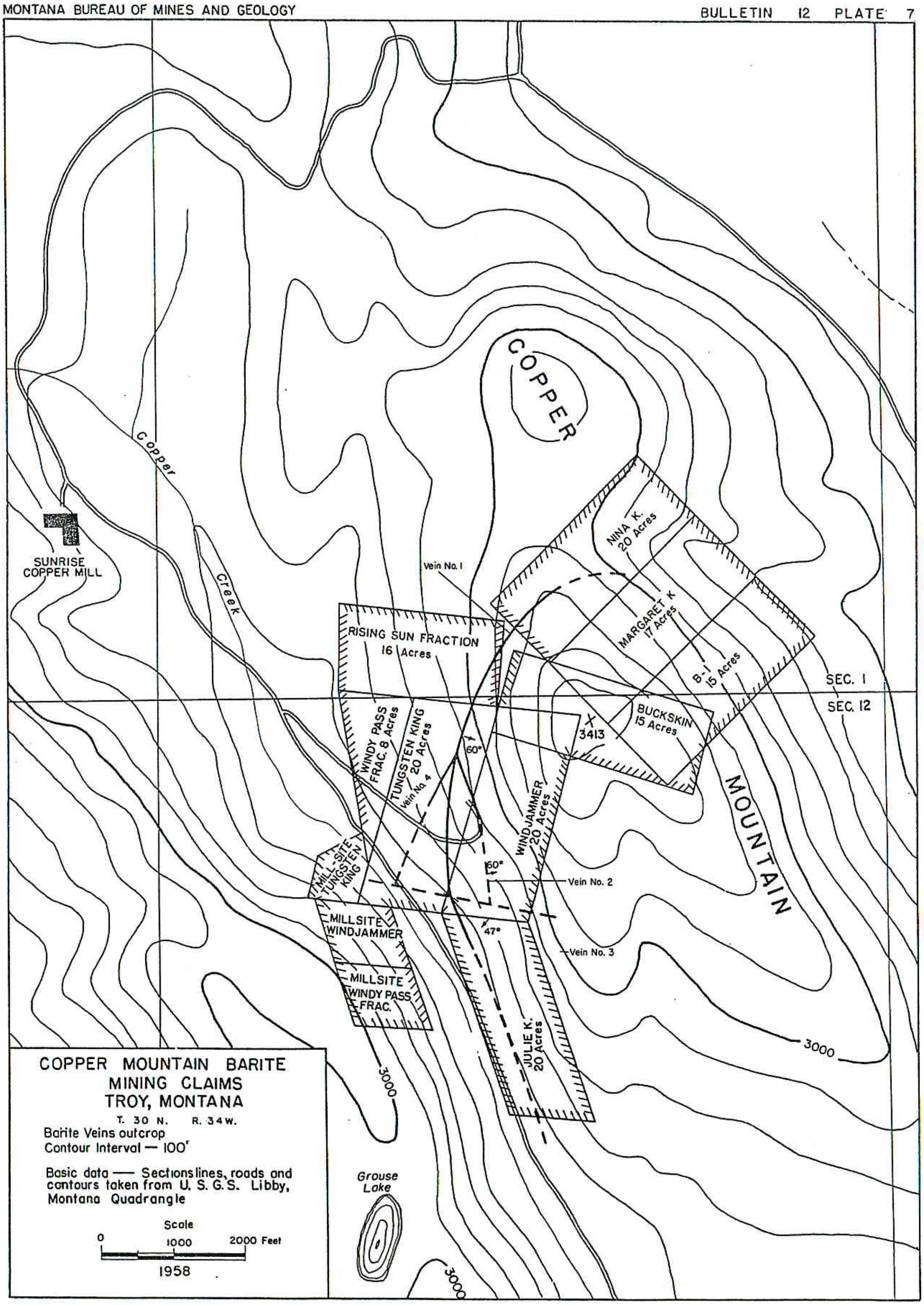
The Kotschevar or Copper Mountain group is in secs. 1 and 2, T. 30 N., R. 34 W. on Copper Mountain in the Troy district. The property consists of nine unpatented lode claims and three mill sites (see pl. 7). The group was purchased in 1958 from James B. Robinson of Spokane, Washington, by Donald and Lendal Kotschevar of Sandpoint, Idaho, and Missoula, Montana. No production has been reported to date (June 1959).

A. PLAN OF FISHER CREEK MINE



B. PLAN OF SNOWSTORM MINE




COPPER MOUNTAIN BARITE
MINING CLAIMS
TROY, MONTANA
T. 30 N. R. 34 W.
Barite Veins outcrop
Contour Interval — 100'
Basic data — Sectionslines, roads and contours taken from U. S. G. S. Libby, Montana Quadrangle
Scale
0 1000 2000 Feet
1958
COPPER
MOUNTAIN
Copper Creek
SUNRISE COPPER MILL
Vein No. 1
Vein No. 2
Vein No. 3
Vein No. 4
RISING SUN FRACTION 16 Acres
NINA K. 20 Acres
MARGARET K 17 Acres
B-1 15 Acres
BUCKSKIN 15 Acres
WINDY PASS FRAC. 8 Acres
TUNGSTEN KING 20 Acres
WINDJAMMER 20 Acres
MILL-SITE TUNGSTEN KING
MILLSITE WINDJAMMER
MILLSITE WINDY PASS FRAC.
JULIE K. 20 Acres
SEC. 1
SEC. 12
3413
60°
60°
47°
3000
3000
3000
Grouse Lake

The property is developed by one 80-foot adit (assessible) on Vein No. 1, and a 35-foot adit on Vein No. 3, and several pits and cuts on the other veins.

Three branching veins and one cross-vein ranging from one to five feet wide strike from northwest to northeast. The three branch-veins dip easterly and the one cross-vein dips southwest. The barite vein on the Julia K. claim (No. 1 on map, pl. 7) strikes about N. 20° W., but swings to a strike of 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 from 30 to 40 inches wide and is composed of dense white barite. The barite assays 92.1 percent barium sulfate and 0.35 percent silica. A split from this vein (No. 2 on map) strikes S. 15° E. 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 it averages 30 inches wide. 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 outcrop on the Buckskin and Windy Pass claims. The Buckskin vein is 3½ feet wide and strikes N. 80° W. and dips 85° NE. The vertical vein (No. 1) on the Rising Sun fraction contains about 3 feet of barite. All veins are in the Wallace formation, which trends about N. 30° W. and dips 60° to 65° S.

Tom Schessler* reports a 3½-foot vein on the Buckskin Claim contains 8 inches of quartz and barite on the hanging wall, 14 inches of yellow crystalling barite in the center, and 20 inches of brecciated barite, ankerite, and siderite on the foot wall. Schessler estimates the barite content of sections of veins to range from 40 to 60 percent. High-grade portions of the veins may assay from 85 to 95 percent $BaSO_4$.

Giant Sunrise

The Giant Sunrise (formerly the Montana Sunrise) is in the Troy district in the NE¼ sec. 14, T. 30 N., R 34 W. The group of claims are on Grouse Mountain about five miles south of Troy. Nineteen unpatented claims and a mill site have been relocated by Wallace Litchfield of Troy (see p. 8B).

Gibson (1948, p. 102) reports a 100-ton mill was constructed in 1934. Mill heads from the mine contained 6 percent lead, 8.50 percent zinc, and 1.20 ounces of silver to a ton.

Development adit Nos. 4, 5, 7, and 10 are 200, 500, 1,000, and 6,000 feet in length respectively. Adit No. 10 follows the dike on a bearing of S. 35° E. All were accessible in 1958.

A quartz-calcite vein, in a dark fine- to medium-grained dike containing plagioclase biotite, quartz, and sericite with accessory chlorite, ilmenite, and zoisite, strikes N. 30° to 35°

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*Personal communication

W. The trend of the dike and vein are approximately parallel. They occur in a grey argillite, quartzite, and sandstone of the Prichard formation.

The vein is from 1 to 3 feet wide. It contains galena, sphalerite, pyrrhotite, chalcopyrite, pyrite, and ilmenite in a gangue of white quartz and calcite. Some chlorite and, less commonly, sericite are associated with the sulfides and quartz. The vein lies near the center of the dike, and other parallel-trending veins occur near the dike contacts. The wall rock is impregnated with sulfides and ilmenite as far as 20 feet from the vein, although the mineralization is not strong enough to make ore.

Ore on No. 7 dump is dark-brown sphalerite, galena, and white quartz gangue.

Liberty Metals crosscut adit No. 11, whose portal is on the Giant Sunrise claim, was driven in a southwest direction in the Prichard formation for a distance of 1,800 feet to intersect veins on the Little Spokane, Silver Strike, and Cabinet Queen claims located on the Grouse Mountain dike.

An assay of the vein near the present face of adit No. 10 supplied by Tom Schessler gave 15.20 percent lead, 3.10 percent zinc, and 3.10 ounces of silver to the ton.

Last Chance

The Last Chance prospect is in sec. 10, T. 30 N., R. 34 W. The property, owned by Elide and Albert Commellini of Spokane, has two unpatented claims, Jack No. 1 and 2. The property is developed by a 240-foot adit and a short drift. No production has been reported from the property.

Two quartz veins in a metadiorite dike are 6 to 8 inches and 2 to 3 feet wide respectively. The 2-foot vein is composed of barren quartz, whereas the other vein contains sulfide minerals. The quartz vein strikes N. 50° W., and the smaller sulfide vein strikes N. 75° W. and dips 45° NE. Small faults from 1 to 6 inches wide contain gouge breccia and parallel the strike of the sulfide structure. Sulfides in order of abundance are galena, sphalerite, arsenopyrite, and chalcopyrite in a gangue of quartz. The dike cuts thin- to medium-bedded quartzite and shale of the Prichard formation, which strikes N. 40° W. and dips 60° SW (see pl. 9B).

A channel sample assayed by Tom Schessler ran 5.0 percent lead, 0.80 percent zinc, 1.20 ounces per ton of silver, and a trace of copper.

Montana Morning

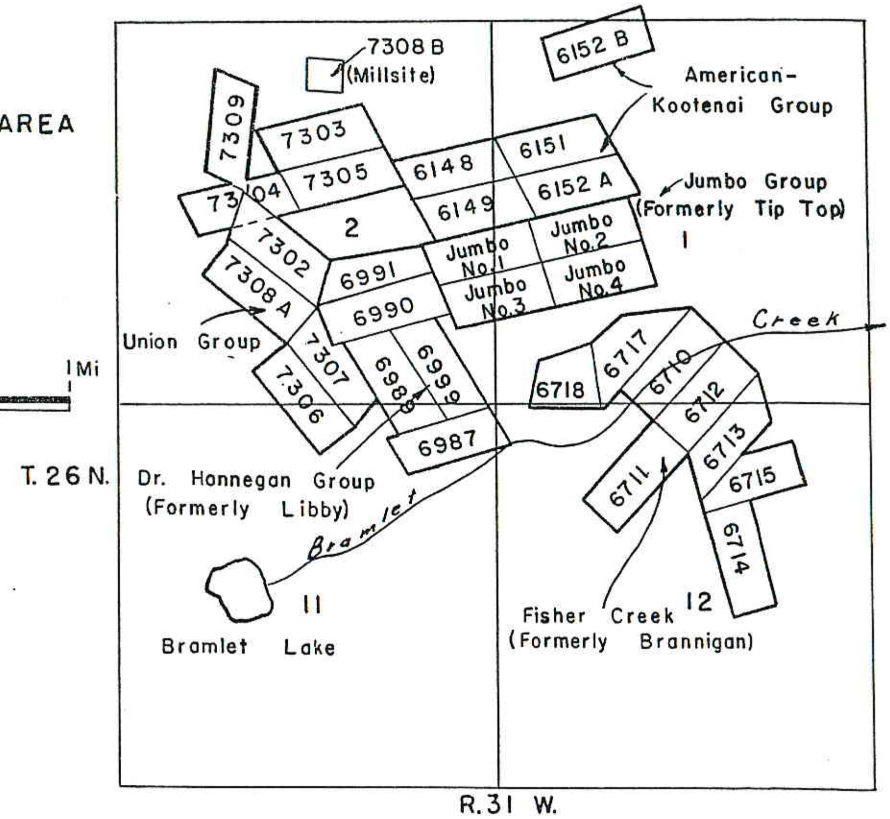
The Montana Morning claims are in the E$\frac{1}{2}$ sec. 28, T. 31 N., R. 34 W., near the southeast end of the Snowstorm dike. The property, owned by John and Violet Molyneaux of Troy, consists of four unpatented claims relocated in 1946.

A. CLAIM MAP of BRAMLET LAKE AREA

From Sketch by Baylord

0 1/2 1 Mi

Scale



B. CLAIM MAP of GIANT SUNRISE PROPERTY

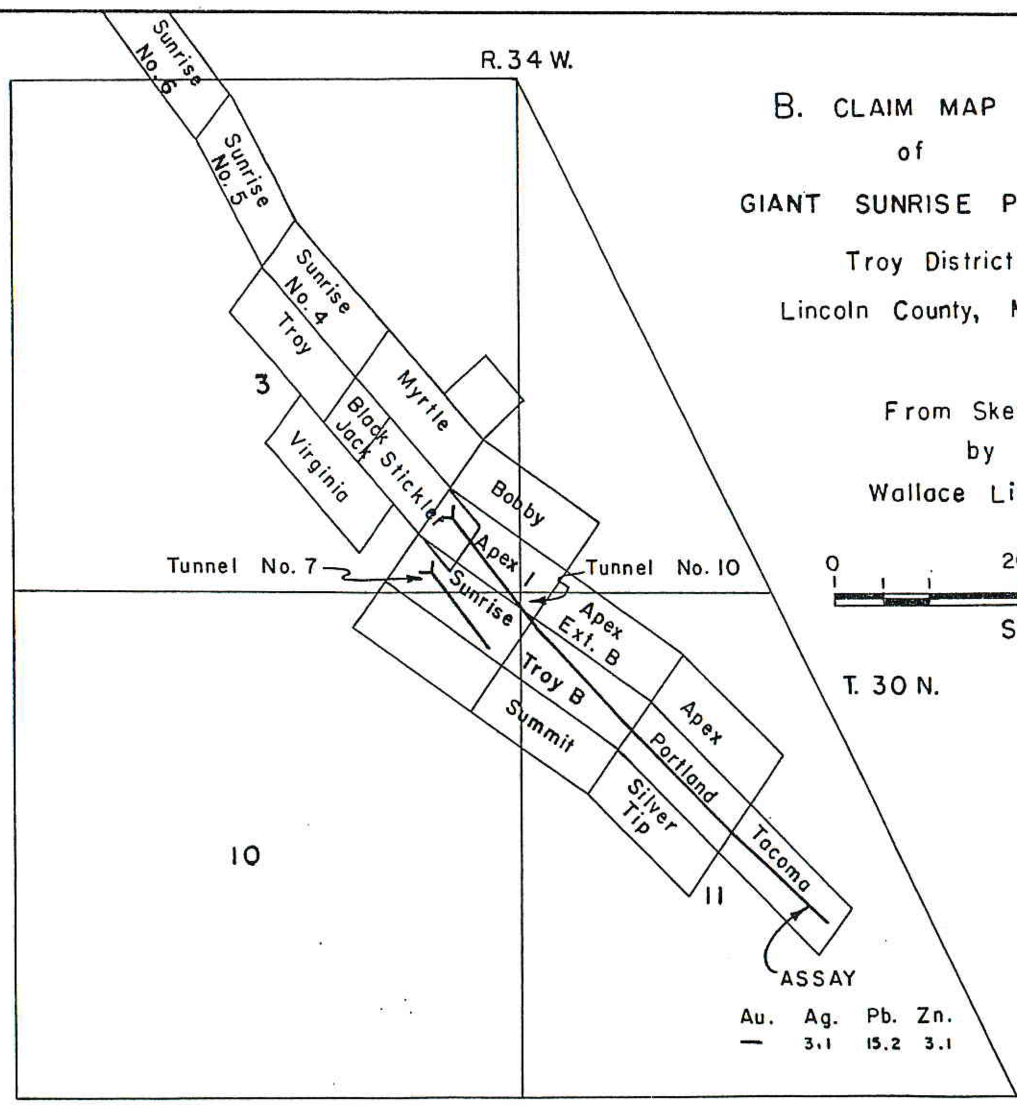
Troy District

Lincoln County, Montana

From Sketch by Wallace Litchfield

0 2000' 4000'

Scale



Development work on Montana Morning No. 3 claim consists of a small open cut and a shallow pit A 350-foot adit, and 80-foot winze, and two short crosscuts develop the vein on the Montana Morning No. 2 claim. All were accessible in 1958.

The vein in the Snowstorm dike strikes N. 10° to 20° W., dips 80° to 85° NE, and ranges from 2 to $2\frac{1}{2}$ feet wide. The metadiorite dike is 15 feet wide. Smaller veins from one to several inches wide are found in fracture zones in the dike and in adjacent sediments. The veins and dikes are in Prichard quartzite and argillite that strike N. 25° W. and dip 50° SW. Sparse amounts of galena, sphalerite, chalcopyrite, and pyrrhotite occur in the quartz vein. Some stoping has been done, and the ore treated at the Snowstorm mill (see pl. 9A).

Grouse Mountain

The Grouse Mountain property is on the west side of Grouse Mountain in the SW$\frac{1}{4}$ sec. 10, T. 30 N., R. 34 W., in the Troy district. The property was discovered and located in 1892 and has been recently relocated by Lawrence Lemier of Libby, Montana.

A crosscut adit driven in a northerly direction intercepted the Grouse Mountain dike at a distance of 1,040 feet from the portal. About 200 feet of drifting, in a northwest and southeast direction, has explored the dike. Several small quartz veins were intercepted.

An 8- to 10-inch vein lies within and parallels the trend of the Grouse Mountain dike. The dike is 145 feet thick and trends in a northwest direction.

The most abundant vein minerals are galena and sphalerite, although some pyrrhotite, arsenopyrite, and chalcopyrite are present. Gangue minerals are quartz and calcite with chlorite and sericite. Pyrite is present in the vein. Ore bodies are lenticular and discontinuous; some post-mineral faulting is present.

Some ore has been stoped from a section of the vein.

Bimetallic

The Bimetallic group includes 13 claims in the S$\frac{1}{2}$ sec. 13 and NE$\frac{1}{4}$ sec. 14, T. 30 N., R. 34 W., in the Troy district. The group is on the southwest slope of Grouse Mountain near the North Fork of Lake Creek.

Four adits have been driven in a north- to northwest direction to explore quartz veins in fracture zones of the Grouse Mountain dike. The dike in this locality has been altered by hydrothermal solutions, and the essential minerals formed were sericite, quartz, chlorite, and carbonate.

Quartz veins up to 8 inches wide have been formed in fractured sections of the dike. The most abundant mineral is quartz which exhibits a ribbon structure; galena, and some pyrite, chalcopyrite, arsenopyrite, and sphalerite are present.

Post-mineral faulting has offset the veins, although the displacement is small. Most of the veins in the oxidized zone contain anglesite, cerussite, pyromorphite, limonite, and manganese oxides.

Daniel Lee

The Daniel Lee Prospect, in sec. 26, T. 29 N., R. 34 W., is northwest of Mount Vernon. Three claims were located by Earnest Williams of Troy in 1958.

A quartz vein, from 10 to 15 feet wide, strikes N. 40° W. and is vertical. The vein, in Ravalli quartzite and argillite, may be continuous for a distance of several miles. One pit has been excavated on the vein.

Sparse amounts of pyrite, chalcopyrite, galena, and covellite are disseminated throughout parts of the vein. Quartz, the most abundant mineral, makes up 95 to 98 percent of the vein material. Sulfide minerals occur within several feet of the surface outcrop; however, oxidized vein material contains hematite and manganese oxides in vuggy sections of the vein. Malachite staining occurs in outcrops, and pyrite casts are common. Sericite and chlorite are present in sulfide vein material.

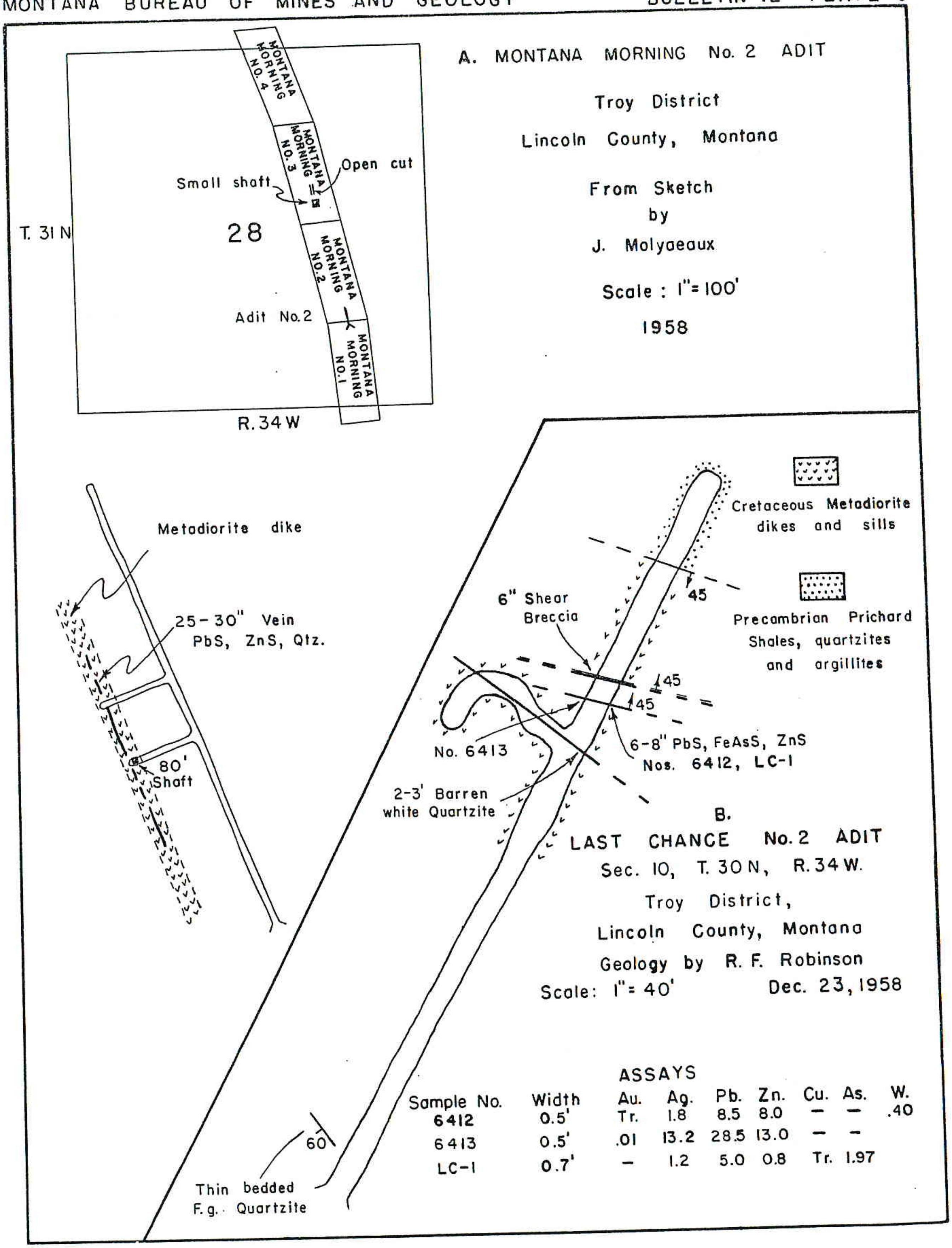
Spar Lake Copper

The Spar Lake Copper prospect is in sec. 16, T. 29 N., R. 34 W., a mile west of Spar Lake. Six unpatented claims were located in 1958 by Messrs. E. Williams, L. W. Rubier, R. Rubier, and B. Rubier. A 1,200-foot road has been constructed to the property, and four bulldozer cuts have been made at intervals across the vein.

A metadiorite dike strikes N. 45° W. The dike is in Wallace quartzite and argillite which trends N. 60° W. and dips 12° to 20° SW. A quartz vein about 9 feet wide occurs near the center and parallels the dike trend. Sparse amounts of pyrite, chalcopyrite, and bornite are found as disseminated masses and grains in the quartz. Massive white quartz makes up 95 percent or more of the vein. Malachite staining is conspicuous for distances of 15 feet on either side of the quartz vein. Oxidized parts of the outcrop contain hematite in casts of pyrite. Sulfide minerals are found within 8 to 10 feet of the surface outcrop.

Bear

Messrs. R. L. and H. E. Bear of Kalispell have reported a quartz vein containing considerable galena and some sphalerite occurs in school sec. 16, T. 31 N., R. 34 W. of the Troy district. The deposit occurs in the NW$\frac{1}{4}$ of the section in a metadiorite dike near the north-south line between secs. 16 and 17. The vein outcrops on a steep hillside and is reported to assay up to 20 percent lead with 3 ounces of silver a ton.



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	

CONCLUSIONS

Ore deposits in the Libby and Yaak River quadrangles are in fissure veins in basic and acidic dikes and sills, and in sedimentary rocks of the Belt series. Mineralization is of the fissure-filling and replacement type; veins are classified as gold-quartz veins, lead-silver-zinc veins, and copper veins. Barite occurs in veins on Copper Mountain in the Troy district. Ore deposits are found in quartz veins, and mineralization is often associated with fracture zones containing sulfides.

Prichard sediments are the more-favorable host rock for ore deposits; however, economic mineral deposits are found in Ravalli and Wallace strata. To date little or no economic mineralization has been found associated with Striped Peak and Libby sediments, although some vermiculite was found in the Bobtail Creek stock in Wallace sediments. Basic and acid igneous dikes have been mapped in Libby sediments, and there is no reason to believe that quartz veins could not occur in or associate with dikes and stocks in these upper Belt rocks.

The more-productive mines in the Yaak River quadrangle are in Prichard quartzite. The Sylvanite district, Duplex and Oro properties have produced gold, silver-lead, and lead-silver-zinc ores respectively. The New Morning Glory mine has been the major producer in the quadrangle.

Major producers in the Troy and Libby districts have been the Snowstorm, Big Eight, Snowshoe, Fisher Creek, and several others. The largest production has been from lead-silver-zinc veins, although gold-quartz veins have produced smaller tonnages of higher-grade ore.

SUGGESTIONS FOR PROSPECTING

Base Metals

The greater number of ore deposits have been found in Prichard quartzite and argillite, although Ravalli and Wallace sediments are host rocks for some deposits.

Fissure veins are often found in northwest-trending dikes or filling smaller east-west fractures. Numerous northwest-striking metadiorite dikes occur southwest of the Leonia fault in Prichard sediments. Quartz veins in the dikes may be located by careful observation of quartz float where mantle rock and soil cover dikes and veins. Sericitic and chloritic alteration of dike rock may also be used as a guide for locating areas of hydrothermal alteration which may indicate the presence of larger veins. The Oro mine appears to be on the Snowstorm dike; prospecting the surface outcrops from the Oro property in a northwest direction may disclose other veins along the dike. Other favorable locations for ore deposits are near the anticlinal and synclinal axis of folds. Deposits in the Sylvanite district and in the Zonolite stock are located near the crest and trough of an anticline and syncline respectively. Prospecting along or near the trace of the Sylvanite anticlinal axis northwest of the Sylvanite mines may reveal other longitudinal or diagonal quartz veins. Fault intersection and areas where close-spaced east-west faults occur may also be favorable locations for mineral deposits.

Metadiorite dikes and acid-igneous dikes and stocks (?) were cut by roads near the head of Benning Creek, a tributary of Keeler Creek in sec. 14, T. 30 N., R. 35 W. Considerable quartz float occurs in the area. The area is worthy of further investigation.

Lead-zinc mineralization was reported found during cedar-logging operations in Studabaker Draw, T. 33 N., R. 33 W. The sulfides were found on a skid trail in the draw. The extent and location of the mineralization is not known.

A number of dikes cross Pipe Creek south of the Pipe Creek divide. Some copper staining was associated with the dikes. Further examination and prospecting is indicated.

Copper-bearing float has been reported near Turner Mountain north of Loon Lake. Two metadiorite dikes were mapped in the area, and quartz veins with sulfide mineralization might occur along the strike of the dikes.

Disseminated pyrite in a strongly-altered igneous rock classified as a syenite occurs in a small outcrop west of a logging road in sec. 6, T. 32 N., R. 31 W. The leached outcrop contains abundant hematite, limonite, sericite, and chlorite. The limonites appear to be an alteration product of pyrite, and some copper may have been present. The outcrop should be trenched to determine the extent and presence of mineralization.

Talc

Mr. Tom Mathews has uncovered a talc deposit in sec. 25, T. 32 N., R. 33 W. A bulldozer cut exposed a talc vein 5 to 6 feet wide for a distance of 20 feet. Another cut exposed talc material from 15 to 20 feet wide for a distance of 30 feet. The status of this deposit is not known.

Clay

Aluminous clays occur in the Clay Creek drainage in secs. 10 and 11, T. 34 N., R. 32 W., south of Reynolds Lake near Clay and Sheepherder Mountains. It is estimated that the material may contain from 20 to 25 percent alumina. More detailed work is required to determine extent and alumina content of the clays.

Other silts and clayey silts are exposed along Seventeen Mile road west of Loon Lake and in Kootenai River valley.

Limestone

In the Yaak River quadrangle in sec. 28, T. 33 N., R. 34 W., a calcareous tuffa occurs on the D. A. Sheffler ranch near the mouth of a small tributary of the Kootenai River. The deposit is approximately one-half mile from the Great Northern railroad.

It is estimated to be 1,200 feet in length, 50 feet wide, and (+) 12 feet deep. It assays from 85 to 90 percent $CaCO_3$. Three other calcareous tuffa deposits occur on the Marion Fisher ranch in the NE$\frac{1}{4}$ sec. 34, T. 33 N., R. 34 W.

Another outcrop of calcareous tuffa is in the SW$\frac{1}{4}$ sec. 8, T. 33 N., R. 31 W. along the road paralleling the east side of Pipe Creek. The calcareous material (No. 17 in Appendix) does not outcrop extensively in the area. It assays 54.20 percent CaO, 38.80 percent CO_2 and 2.10 percent SiO_2; MgO is nil in the sample.

The material may have been deposited by a spring.

Calcareous tuffa occurs near the Jack Garrison ranch on the J. Neil haul road on Callahan Creek south of Troy. A sample of the material (No. 13 in Appendix) assayed 54.00 percent CaO, 39.80 percent CO_2, (91.3 percent $CaCO_3$), and 1.80 percent SiO_2. There was no magnesium oxide in the sample.

The more-favorable locations for higher-grade limestone deposits are in the Wallace and Libby formations. Some limestone horizons in the Libby formation outcrop in the vicinity of Loon Lake. A sample of an outcrop of Libby (?) magnesian bearing limestone located 2.6 miles east of the Libby bridge on U. S. Highway 2 assayed 32.00 percent CaO, 45.50 percent CO_2, and 21.50 percent MgO.

Quartzite

White to grey quartzite beds in the Ravalli and less commonly in the Prichard formation contain about 80 percent silica, and 1.75 percent iron. The silica content of the quartzite is not high enough to be considered a metallurgical grade quartzite. Well-sorted quartz sands, which to date have not been found in the quadrangles, may contain sufficient silica to be used as a flux in the smelters. Some diatomaceous earth (?) in a 35-foot bed was reported found by H. P. Reinshagen of Libby, Montana.

Flagstone

Wallace beds in the vicinity of Kootenai Falls along Highway 2 may be a source of flagstone. Natural cleavage is present in outcrops in the area.

Near the top of the Striped Peak formation in Big Foot Creek in the Yaak River quadrangle a finely-banded red-green argillite horizon occurs that would make excellent flagstone if natural cleavage planes were present. Natural cleavage is not well-developed in this particular locality.

Natural cleavage may be better-developed in Belt sediments along axis of moderate- to tightly-folded anticlines and synclines throughout the quadrangles.

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Appendix.--Analyses of limestones and quartzites in Lincoln County, Montana

Sample No.	Location	*CaO %	MgO %	CO_2 %	Al_2O_3 %	Fe %	SiO_2 %
1.	Surface, Libby fm., 1½ mi. W. of Libby bridge U. S. Highway 2	5.20	---	1.90	13.70	0.80	65.50
2.	Surface, Libby fm., 2.6 mi. E. of Libby bridge U. S. Highway 2	32.00	45.50	0.40	Nil	21.50	0.20
3.	Surface, SW¼ sec. 3, T. 32 N., R. 34 W.	8.30	---	1.60	9.40	1.80	66.00
4.	Surface, N½ sec. 10, T. 32 N., R. 33 W.	10.50	---	2.50	12.90	4.20	55.70
5.	Surface, sec. 35, T. 32 N., R. 31 W.	17.80	14.60	1.50	9.10	3.90	47.40
6.	Surface, sec. 22, T. 32 N., R. 31 W.	10.00	10.20	1.80	12.40	3.60	56.70
7.	Surface, sec. 24, T. 33 N., R. 32 W.	20.00	15.20	2.00	9.50	3.30	44.20
8.	Surface, SE¼ sec. 4, T. 32 N., R. 33 W.	15.60	12.60	1.60	11.70	3.90	44.50
9.	Surface, SE¼ sec. 4, T. 32 N., R. 33 W.	13.50	16.90	1.50	9.90	1.60	48.40
10.	Surface, sec. 4, T. 32 N., R. 33 W.	16.50	11.70	1.80	11.60	3.00	46.50
11.	Surface, sec. 2, T. 32 N., R. 34 W.	24.20	14.40	1.90	7.80	1.80	41.00
12.	Surface, SW¼ sec. 21, T. 32 N., R. 34 W.	18.60	19.60	1.80	11.40	11.50	28.80
13.	Surface, Jack Garrison ranch in Libby quadrangle	54.00	39.80	0.30	0.50	Nil	1.80
14.	Surface, sec. 11, T. 32 N., R. 34 W.	13.50	16.30	2.30	10.50	5.20	47.70
15.	Surface, "B" Spur, Yaak Lookout road, NE¼ sec. 1, T. 32 N., R. 34 W.	9.70	9.80	2.20	13.70	3.40	44.60
16.	Surface, 35' side, sec. 16, T. 33 N., R. 31 W.	20.30	20.60	2.00	9.10	3.20	49.40

Appendix.--Analyses of limestones and quartzites in Lincoln County, Montana (Cont'd)

Sample No.	Location	*CaO %	Mgo %	CO_2 %	Al_2O_3 %	Fe %	SiO_2 %
17.	Surface float, SW¼ sec. 8, T. 33 N., R. 32 W.	54.20	38.80	0.40	6.50	N.1	2.10
18.	Surface, 18' wide, sec. 8, T. 33 N., R. 32 W.	11.70	8.70	2.20	9.80	3.30	54.50
19.	Surface, Virginia Garrison clay deposit 2 mi. SE Yaak, Montana	1.40	Nil	3.50	25.20	2.90	54.00
20.	Surface, ¼ mi. SE Gunsight Mtn., S½ sec. 23, T. 33 N., R. 33 W.	---	---	---	---	1.60	82.20
21.	Surface, SW¼ sec 30, T. 32 N., R. 34 W.	---	---	---	---	1.60	80.70
22.	Surface, sec. 8, T. 34 N., R. 34 W.	---	---	---	---	1.50	80.10
23.	Surface, sec. 19, T. 33 N., R. 33 W.	---	---	---	---	2.20	75.50
24.	Surface, center sec. 19, T. 33 N., R. 34 W.	---	---	---	---	1.80	79.30

* CaO = Calcium Oxide, MgO = Magnesia, Al_2O_3 = Alumina, CO_2 = Carbon Dioxide, Fe = Iron, SiO_2 = Silica.