STATE OF MONTANA

M. A. Brannon, Chancellor, The University of Montana

BUREAU OF MINES AND GEOLOGY

Francis A. Thomson, Director

MEMOIR No. 9

A GEOLOGICAL RECONNAISANCE OF THE TOBACCO ROOT MOUNTAINS, MADISON COUNTY, MONTANA

By

WILFRED TANSLEY,

PAUL A. SCHAFER,

LYMAN H. HART

MONTANA SCHOOL OF MINES

BUTTE, MONTANA

June, 1933

A. WEST FRONT OF THE RANGE
From near Twin Bridges. Alluvial fan in foreground.

B. OLD BALDY MOUNTAIN.
View from the east side of Alder Gulch. Placer diggings show at the extreme right. Paleozoic rocks cap the mountain.

C. UPPER SOUTH BOULDER CREEK
From about two miles south of the Mammoth mine looking south. A typical glaciated valley.

D. LOWER SOUTH BOULDER CREEK.
From about four miles north of the Mammoth mine looking south. A typical unglaciated valley.

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MADISON COUNTY, MONTANA

Part I. Areal Geology
by
Wilfred Tansley and Paul A. Schafer

Part II. Ore Deposits
by
Lyman H. Hart

MONTANA SCHOOL OF MINES

BUTTE, MONTANA

July, 1933

FOREWORD

This report, "A Geological Reconnaissance of the Tobacco Root Mountains, Madison County, Montana", represents the study of an area which includes some of the famous placer fields of the early west. As has been the case with many areas noted for the production of placer gold, the yield of the veins has been far below that of the gravels; in other words, much of the "mining and milling" had been accomplished before the arrival of man upon the scene. Nevertheless, sufficient of the load gold deposits have escaped the processes of erosion to justify their exploitation, and it is the purpose of this publication to aid the intelligent development of quartz mines within the area.

The division of the publication into two parts–the first describing general geologic features, and the second describing the ore deposits–is a logical arrangement, and its adoption enabled the Bureau to utilize the skilled services of an engineer who has had years of experience in detailed examination of many of the properties of the district.

No attempt has been made to describe every property or prospect, and the omission of a specific property from the list of those mentioned is no more to be construed as an reflection upon it, than is the inclusion of a property to be considered as an endorsement of it. The aim has been rather to describe the thoroughly typical properties in each district, so that the intelligent layman or prospector might be able to interpret his observations on other properties to those described.

Francis A. Thomson,
Director

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A GEOLOGICAL RECONNAISSANCE OF THE TOBACCO ROOT MOUNTAINS, MADISON COUNTY, MONTANA

PART I

AREAL GEOLOGY

By Wilfred Tansley and Paul A. Schafer

INTRODUCTION

The name Tobacco Root Mountains originated from the fact that in the early days when tobacco was scarce a species of mullein which grew in the hills was gathered, dried, and mixed with kinnikinic to serve as a substitute for tobacco. It is said that John Edwards, sometime in the sixties, gathered the mullein and gave the name Tobacco Root Mountains to the hills from which the plant was collected.

Gold has been won from the Tobacco Root Mountains in fluctuating quantities since 1863, though of late years the output has declined considerably. This has been due in part to exhaustion of the rich placer deposits and in part to neglect of gold mining since the World War in favor of more lucrative occupations. Not since the early days, when gold mining was the main activity in the district, have so many men been engaged in search for the precious metal as during 1931 and 1932. The general curtailment of business activity and failure to secure employment have enforced changes, and men have returned to the hills to glean a living from the rocks. Records in the office of the county recorder show that during the months of June, July, August, and September of the year 1930, there were 60 locations filed in Madison County, whereas in 1931 over the same period there were 204. Activity during 1932 seems in nowise to have decreased. This indication of increasing industrial importance as well as the scientific interest offered by the deposits of the Tobacco Root Mountains induced the Montana State Bureau of Mines and Geology to begin an investigation of the area.

The purpose of the report is to present a reconnaissance geologic map of the Tobacco Root Mountains, as hitherto none has been available for distribution to those interested in the area; and by a survey of the ore deposits to collect sufficient information to enable mining men to understand the general characteristics of these deposits. The data, though unavoidably incomplete, should be sufficient to aid materially in future mining development.

The geologic field work which forms the basis of this report began during the summer of 1931 with a reconnaissance survey by Wilfred Tansley assisted by Arthur O. Wilson. During the summer of 1932 L. H. Hart devoted his time exclusively to mineral deposits while Wilfred Tansley and Paul A. Schafer continued areal mapping.

The base map used is a composite of the Three Forks and the Dillon topographic sheets, and maps of the Madison National Forest, issued by the Forest Service. Where feasible, distances for geologic locations between section corners were obtained by odometer using compass for direction; elsewhere distances were measured by pacing. Insofar as possible, locations somewhat in error were corrected by these methods.

Geologic literature on the area is scant. The following publications refer to the particular district described; others less closely related are mentioned as footnotes.

1. Hayden, F. V., Preliminary report of the U. S. Geol. Survey of Montana and portions of adjacent Territories: U. S. Geol. Survey of Territories, Fifth Annual Report, pp. 33-43, 1872.
2. Peale, A. C., Report on minerals, rocks, thermal springs, etc.: U. S. Geol. Survey of Territories, Fifth Annual Report, p. 171, 1872.
3. Hayden, F. V., U. S. Geol. Survey of Territories, Sixth Annual Report, p. 64, 1873.
4. Peale, A. C., U. S. Geol. Survey, Geol. Atlas, Three Forks folio (No. 24), 1896.
5. Shaler, N. S., Loess deposits of Montana: Geol. Soc. America Bull., vol. 10, pp. 245-6, 1899.
6. Winchell, A. N., Mining districts of the Dillon Quadrangle, Montana, and adjacent areas: U. S. Geol. Survey Bull. 574, 1914.

A topographic survey of the area, which comprises part of the Three Forks and Dillon quadrangles was made by Frank Tweedy in 1886-87-88. The map of the Dillon quddrangle was published in 1893 and that of the Three Forks quadrangle, in 1896. Both maps are on a scale of 1 to 250,000 (1 inch = approximately 4 miles) and have a contour interval of 200 feet. That portion of the Tobacco Root Mountains lying east of the 112th meridian was studied by A. C. Peale and is included in the geologic report, the Three Forks Folio, published in 1896.

A geologic report on the mining districts of the Dillon quadrangle and adjacent areas by Alexander N. Winchell, was published in 1914.

It would be a great pleasure to acknowledge all assistance and numerous courtesies extended by those interested in the mining industry of the district, for everyone seemed anxious to do all possible to advance the work. Special thanks, however, are due to Mr. Alexander Leggat of Butte, Mr. C. F. Morris and Mr. M. I. Leydig of Pony, Mr. R. W. Rossiter of Sheridan, and Mr. M. C. Holbert of Virginia City. President Francis A. Thomson of the Montana School of Mines, under whose direction the work was carried on, was ever ready to give advice and assistance. Dr. Eugene S. Perry, of the Department of Geology, gave freely of his time, and some of the data concerning Paleozoic, Mesozoic, and Cenozoic rocks were collected by him. Drafting of maps and sketches was done by Mr. Uuno M. Sahinen, as well as the compilation of some of the statistical data concerning mineral production.

LOCATION AND ACCESSIBILITY

The Tobacco Root Mountains lie between parallels 45° and 46° north and are bisected by the 112th meridian. The city of Butte lies about 40 miles to the northwest, and the southern end of the range is about 45 miles north of Yellowstone Park. The range, which lies wholly within Madison County, covers an area of approximately 500 square miles, and forms the divide between Madison River and Jefferson River. The main axis is a curve, concave to the east. Beginning at a point about 5 miles southeast of Whitehall, the range trends slightly west of south for about 15 miles. It then swings southeast and continues for about 25 miles to Virginia City. Its maximum width of 25 miles is attained between Twin Bridges and Revenue. In the neighborhood of Virginia City the continuity of the range is broken by a low gap, and that portion to the south is known as the Gravelly Range, although the whole really constitutes a single physiographic unit.

The Northern Pacific Railway and the Chicago, Milwaukee, and St. Paul Railway, with stations at Whitehall and Jefferson Island respectively, pass close to the northern limit of the range. The Alder branch of the Northern Pacific Railway skirts the western side, and the Pony-Norris branch the northern part of the eastern side of the range.

Keeping near the foothills, one may pass completely around the range by automobile over graded roads which connect with the state highway at Sappington and Whitehall. The Vigilante Trail, a highway between Butte and West Yellowstone, named to commemorate the deeds of the Vigilantes, passes along the west and south sides of the range. Many branch roads, which follow canyon-like valleys for several miles into the heart of the range, are passable by automobile. Mill Creek, east of the town of Sheridan, can be followed by car for 11 miles. An additional 3 miles of road, at present under construction,

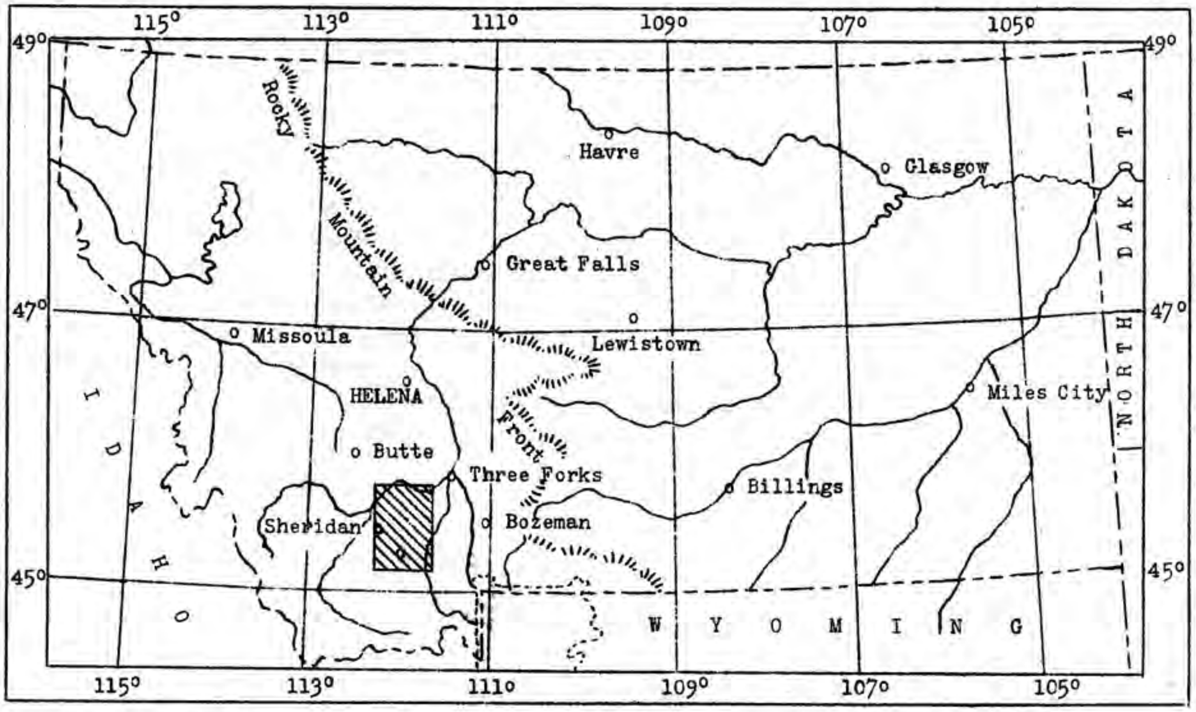

Figure 1.--Index map of Montana showing location of area included in this report.

will connect this road with Branham Lakes, which lie in a magnificent cirque at the head of the North Fork of Mill Creek. These mountains have much to offer in scenic beauty.

C L I M A T E   A N D   V E G E T A T I O N

The region is high and semi-arid, with an annual precipitation of from 10 to 15 inches.

Precipitation reported at Virginia City (in inches and hundredths) for 1930.[1]

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
0.40	0.56	0.67	0.82	0.79	0.96	1.56	1.96	1.45	2.38	0.31	0.82	12.67

The maximum and minimum temperatures are about 90 degrees and minus 30 degrees respectively, but these figures alone are apt to convey an erroneous impression. The low winter temperatures are accompanied by a dry and moderately calm atmosphere, so that stock may be raised on the ranges without shelter. Oppressive weather is not experienced in summer; nights may even be chilly, as the air cools rapidly by radiation, the range of altitude being from 5,000 to 10,000 feet above sea level.

The major portion of the area lies within the Madison National Forest, where medium-sized pine, fir, spruce, and poplar trees clothe the slopes. A sufficient quantity of timber of the proper size for mining purposes is readily available. Sagebrush grows everywhere from the lowest elevations almost to timber line. Grasses in the valleys and bench lands afford good grazing.

1. Report of the chief of the U. S. Weather Bureau 1930-31, p. 193.

M I N I N G   D E V E L O P M E N T

Gold in the Tobacco Root Mountains first became known with the discovery of placers in Alder Gulch in 1863. Placer gold in Montana was first discovered at Gold Creek, near Garrison, in 1852, and rich placers were opened near Bannack in 1862. News of the finds spread rapidly to other states, and many miners came from the placer fields of California and lode mines of Colorado to the new fields of Montana. Although placer-ground was found along many mountain streams, attention was soon turned to lode deposits and both types of mining flourished for at least three decades.

Development progressed in all parts of the area almost simultaneously. Norwegian Creek near Norris was exploited in 1864 and the Pony district was made known in the early seventies. In 1865 a ten-stamp mill was erected on Wisconsin Creek in the Sheridan district. Prospecting was particularly active in the seventies, when most of the important mines were located. From 1880 to 1890 many abandoned mines were reopened; this period was notable for rapid development and for successful operation. Gold dredges were first introduced into Montana at Bannack in 1895, and shortly after, a dredge was moved to Alder Gulch. The period from 1890 to 1900 was one of most successful operations, and many rich mines, such as the Mayflower, the Boss Tweed, and the Clipper, were exploited. After 1900 lode mining was intermittent and on the decline; however, occasional properties were operated with much success. Dredging of placers continued with profit until 1923 when the Conrey dredges were removed.

The progress and success in mining operation can best be measured by examination of tables of production in the latter part of this report.

P H Y S I O G R A P H Y

RELIEF AND DRAINAGE

The maximum relief within the area mapped is about 5,600 feet. Mount Jefferson (elevation 10,600 feet), is about the center of the range, and although attaining the highest elevation it is not a dominant nant point since many of the surrounding peaks rise to 10,000 feet. The crest of the range may be followed, at elevations of 9,500 feet, or over, for many miles. The lowest elevations within the area, which occur along the valleys of Jefferson and Madison rivers, are about 5,000 feet. Slopes have been locally steepened by glaciation, and cirques at the heads of some valleys present precipitous walls for several hundred feet. Alluvial fans, particularly on the west central side of the range, moderate the slopes and reach, in gently concave profiles, from the valley floor for varying distances up the mountain-side.

The region is east of the Continental Divide, and the drainage is to the Gulf of Mexico by way of Missouri and Mississippi rivers. Drainage from the west side of the range flows into the Jefferson and its tributary, Ruby River, and that from the east slopes flows to Madison River. These two streams then unite with the Gallatin, near the town of Three Forks, to form Missouri River. Though many streams dissect the range, only those occupying valleys which stretch far into the mountains are permanent streams and even these are subject to marked seasonal variation. Some gulches carry a small stream in the upper part, which disappears beneath the surface on reaching the porous alluvial fan. The streams commonly have steep gradients, sometimes as much as 700 feet per mile, except where accumulations of debris flatten them, sometimes producing lakes. There are many lakes in the higher parts of the mountains, and, by artificial dams, the capacities of many of these have been increased for irrigation purposes.

GENERAL FEATURES

Although the district forms part of the northern Rocky Mountain physiographic province[2] it also exhibits some features characteristic of the Basin and Range province in southwestern United States. The general topography is that of a rugged, mountainous region dissected by stream erosion and modified by glaciation.

2. Fenneman, N. M., Physiography of the western United States, pp. 215-217, 1931.

The western margin of the range, facing Jefferson River, presents a steep and rugged front, deeply dissected by streams which tumble down short, narrow, and sharply inclined canyons. This mountain front plunges into the sweeping slope of a great composite alluvial fan along a smooth, gently curved, line. The spurs between canyons terminate in sharply truncated faces as though they had been sliced off evenly with a knife. The crest line loses altitude gradually northward, finally merging with the flat alluvium of the Jefferson Valley. The southern portion of the western front, however, slopes steeply into the huge fan which stretches from Sheridan to Twin Bridges. Here the range is cut off along a line extending from the mouth of Dry Gulch to Virginia City.

The west front is characterized by two distinct types of topography which are separated approximately by Mill Creek. South of Mill Creek, between Sheridan and Laurin,[3] the topography is subdued; hills and ridges have gently curving slopes; valleys are relatively wide with gently stream gradients; the mountains merge southwestward into the Ruby Valley almost imperceptibly. North of Mill Creek a marked difference is apparent. Peaks and ridges are high and rugged; valleys are narrow with steep gradients; and the higher summits reach approximately the same elevations--10,000 feet above sea level.

From Alder Gulch, between Alder and Virginia City, the region slopes gradually upward to the north and northeast, and the surface features are uniform the entire distance to the crest of the range, here marked by Ramshorn and South Baldy mountains.

The east side of the range rises from the valley to the crest line without an abrupt change in slope. Alluvial fans are uncommon, except locally along the valleys of North and South Meadow creeks.

It is difficult to explain by any other theory than that of faulting, the combination of abrupt change in slope along a straight course, the development of alluvial fans, and the presence of facetted or truncated spurs. Thus, these features in combination are abundant evidence of faulting, even though actual fault exposures are wanting. A fault, then, is inferred to extend along the western front of the range from Renova Hot Springs to Dry Georgia Gulch near Twin Bridges, where observed faults cut obliquely to it and produce a short angular bend in the mountain front.

In a general way, the mountains may be likened to a block hinged on one side and thrust up on the other, producing a long gentle east slope and a steep westward-facing scarp.

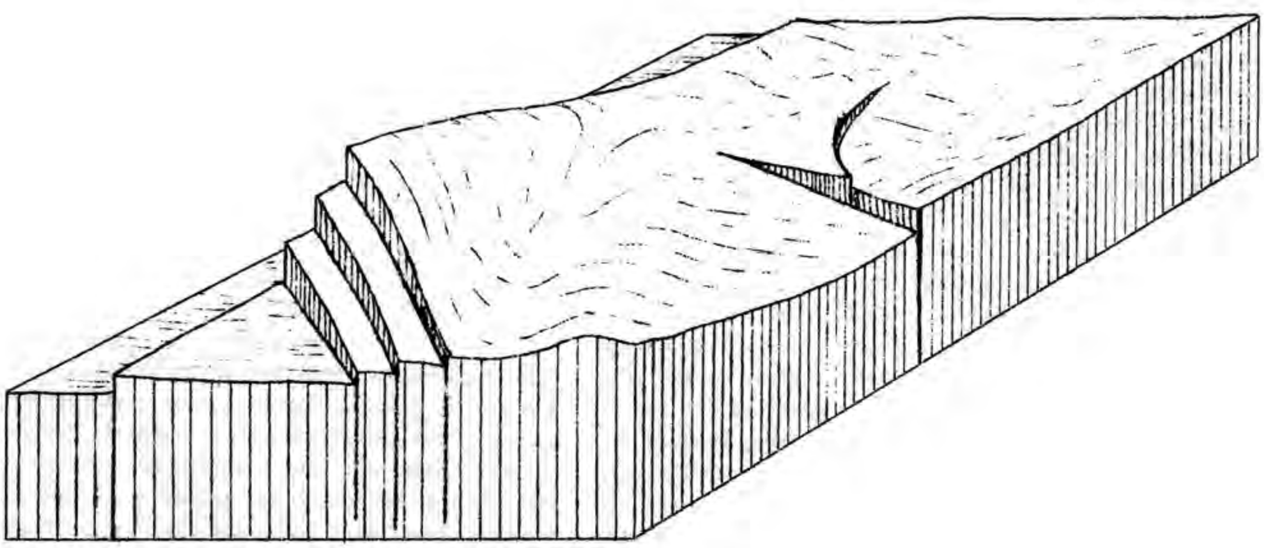

Figure 2.--Stereogram illustrating diagramatically the origin of the main topographic features of the Tobacco Root Mountains.

The uplift of this earth segment rejuvenated the streams, causing them to cut deep,narrow canyons into the higher portions of the range, and to spread the detritus along the base of the mountain front over the flat valley floor of Jefferson River.

3 Locally mispronounced "Loray".

Before the elevation of this region, a rolling surface of relatively low relief existed. Occasional remnants of this ancient surface, elevated high above the former level, have escaped the vigorous etching of the rejuvenated streams. The alignment of these remnants shows that the former land surface was gently tilted eastward and southward by the uplift of the western margin. Such deformation substantiates the evidence previously discussed pointing to differential uplift. Since this surface is well exposed between the villages of Laurin and Norris, it may be called the Laurin-Norris erosion surface. From Laurin eastward toward McAllister this surface can be traced over the top of the range. But northwest of Laurin, about 6 miles, near Mill Creek, its identity becomes lost where faulting and resulting erosion have destroyed it. Between Harrison and Revenue, the dissected Laurin-Norris surface rises gently to the crest of the range, broken only along a line reaching from Pony to a point on North Meadow Creek a few miles west of Revenue. On the north side of Madison Lake and along the north rim of lower North Meadow Creek valley, the old surface terminates abruptly at a fault which has depressed the southern segment to a level below lake beds and alluvium. A prominent escarpment marks the position of the fault. Since this surface was well developed on the granite before the Bozeman lake beds (Oligocene-Miocene) were deposited, it is apparently of early Tertiary age (Eocene-Oligocene).

GLACIATION

Glacial erosion and the deposition of detritus carried by the ice have affected the topography of the higher portions of the range. The wide, U-shaped, glaciated upper parts of the valleys present a striking contrast to the narrow, rugged, V-shaped, unglaciated lower valleys. The contrast is apparent during the ascent of many valleys. South Boulder Creek is an excellent illustration. The abrupt passage from an unglaciated to a glaciated topography occurs just above Mammoth. (See pl. 2, C and D.) Similar features are well developed on Cataract Creek near Pony, on Willow Creek near Potosi Hot Springs, and on North and South Meadow creeks, Wisconsin, Indian, and Mill creeks.

Considerable evidence points to an early and intense stage of Pleistocene glaciation, when the greater portion of the mountains was blanketed with ice which sent long tongues out into the valleys well beyond the mountain front. Remnants of terraces, high above the present stream levels, marking the positions of the early ice-filled valleys, may be seen along South Boulder Creek, Willow Creek above Potosi, Wisconsin Creek, and the upper part of Cataract Creek. Exposed in a road cut, near Norris, is a portion of a terminal moraine of this older glaciation. The material is unstratified clay, sand, and boulders, the latter attaining diameters as great as three feet. The boulders are principally gneiss and granite, considerably altered. A similar occurrence exposed in a cut on the highway between Harrison and Sappington contains even larger boulders. About two miles north of Pony, on the east side of the highway, are granite and gneiss boulders ranging in size up to ten feet in diameter. They lie on a fairly level surface above lake bed deposits, two miles east of the mountains. It seems improbable that these boulders could hafe been carried to their present position by any agent other than glaciation.

The morainal debris deposited during the melting of the ice of a younger glaciation is responsible for much of the rough and hummocky surface of the mountain-valley floors. Terminal or recessional moraines, marking the position of the front of the ice during a period when melting kept pace with forward movement, caused the accumulation of large amounts of clay, sand, and gravel; and these deposits occur in all valleys that reach the higher parts of the range. Usually three of these moraines are present in each valley at intervals of two to five miles; the upper one forms an effective dam across the front of the high, amphitheater-like cirques. Some of the moraines caused lakes to form behind them by obstructing the drainage. Certain of these moraine-dammed lakes (glacial lakes) have been drained by the deepening of their outlets, leaving wide, level marsh-lands as evidence of their former existence.

LANDSLIDES

Features which sometimes look like moraines, are produced by landslides. Many of the valleys, exaspecially in the higher parts of the range, contain great masses of this material. Bear Gulch is dammed by a huge landslide (locally called 'the slide').

Near Virginia City conditions are especially favorable for landslides. Basalt lava-flows lie on an uneven surface of soft clay and volcanic ash. Where valleys have cut deeply into this material, the load becomes too great for such a weak support and the basalt slides into depressions over the wet clay lubricant. Small hills and undrained hollows, often containing lakes, are characteristic of landslide topography. Much of the surface in the vicinity of Axolotl Lakes owes its origin to landslides. About three miles south of Axolotl Lakes there is a basal cliff about 900 feet high from which material is falling at present.

Landslides may be distinguished from moraines by the kinds of rocks which they contain. For example, the Bear Gulch landslide is made up of only granite and limestone boulders, derived from the south and north sides of the valley respectively. Since gneiss is the predominant rock in the gulch above the slide, a glacial moraine at this place would be composed mainly of that material.

DESCRIPTION OF ROCK FORMATIONS

The succession of geologic formations exposed in the Tobacco Root Mountains is as follows:

Geologic formations exposed in Tobacco Root Mountains

	Thickness (Feet)	
Cenozoic		
Quaternary		
Alluvium and glacial drift		Sand, gravel, boulders, and clay.
Tertiary		
Bozeman lake beds		Conglomerate, sand, clay, and volcanic ash.
Unconformity		
Mesozoic		
Cretaceous		
Livingston formation	1,000	Agglomerate and lava flows.
Unconformity		
Montana and Colorado formations	1,800-2,000	Shale and sandstone.
Kootenai (Dakota) formation	800-1,000	Sandstone and shale with thin band of gastropod limestone near middle.
Jurassic		
Morrison (?) formation	?	Variegated shales.
Ellis formation	300-500	Arenaceous and argillaceous limestone and quartzite; oyster beds.
Unconformity		
Paleozoic		
Permian		
Phosphoria formation	100	Shale, quartzite, and limestone; beds of oolitic phosphate rock.
Pennsylvanian		
Quadrant formation	300-500	Black and cherty shale, quartzite, limestone; red band at base.
Mississippian		
Madison formation	1,200-1,500	Massive cliff-forming jaspery limestone, laminated limestone; fine grained black limestone in lower part, sandy at base.
Devonian		
Three Forks formation	100-200	Orange and green and black shale, carbonaceous in places.
Jefferson formation	700-1,000	Massive black magnesian saccharoidal fetid limestone.
Unconformity		
Cambrian		
Gallatin formation	800-1,000	Trilobite limestone, mottled limestone, and pebbly limestone separated by bands of shale.

Paleozoic - continued		
Cambrian - continued		
Flathead formation	400-500	Pink quartzite, shaly sandstone, and shale with some glauconitic limestone.
Unconformity		
Pre-Paleozoic		
Beltian		
Belt series	5,000	Fine-grained shale underlain by greenish-gray arkose and arkosic conglomerate.
Unconformity		
Pre-Beltian		
Cherry Creek series	8,000	Hornblende-garnet gneiss, crystalline limestone, quartzite, mica schist, and quartz-feldspar gneiss of sedimentary origin.
Unconformity		
Pony series		Dark and light colored gneiss and schist, sedimenttary and igneous origin.

Lithologically, there are three distinct groups of pre-Cambrian rocks in this region: gneisses and schists which, because they are well exposed in the vicinity of Pony, will be called the Pony series; gneisses, schists, quartzites, and limestones of the Cherry Creek series; and the later, less metamorphosed Belt series. The Pony series, containing rocks of both igneous and sedimentary origin, is undoubtedly older than the Cherry Creek. It has been considered to be of Archeozoic age. The Cherry Creek group, since it is younger than the Pony group and contains only rocks of sedimentary origin, was thought to be of Algonkian (late Proterozoic) age.[4] There is no positive evidence that such a division of the Pony and Cherry Creek rocks is justified. Both groups might belong to either the Archean or Proterozoic eras. Because correlation with known Archean and Proterozoic formations is impossible at this time, these metamorphic rocks will be called pre-Beltian, since they are definitely older than the Belt series, which is late Proterozoic (Algonkian).

PRE-BELTIAN

Pony Series

The Pony series is made up of both light and dark colored gneisses and schists. A band of feldspar-quartz gneiss, containing hornblende as a subordinate constituent, reddish-brown on the weathered surface, extends from near the Mammoth mine, passing through the town of Pony and thence along the north side of the road to Norris. Immediately north of this formation is a variety of dark and light-colored gneisses and schists. This series is well exposed in the South Boulder canyon from its contact with Paleozoic rocks, about 4 miles north of Mammoth, nearly to the forks, 4 miles above Mammoth. Thence this series swings southwestward, lying between the base of the Paleozoic sediments and the Cherry Creek group. The Pony-Cherry Creek contact lies near, and almost parallel to Wisconsin Creek, passing thence near the Bismark mine on South Boulder Creek where it is cut by quartz monzonite. From Red Bluff, near Norris, the Pony gneisses swing southward toward Ennis Lake where they are lost beneath lake beds and alluvium of Madison River and Meadow Creek valleys.

Southwest of McAllister they are exposed again, flanked by Cherry Creek rocks on the west and by lake bed and alluvial deposits on the east. The contact of the Pony series with the Cherry Creek occurs about three miles southwest of McAllister and trends toward the crest of the divide between Ennis and Virginia City where it is lost beneath the Virginia City lava flows.

4. Peale, A. C., U. S. Geol. Survey Geol. Atlas, Three Forks folio (No. 24), 1896.
Van Hise, C. R., and Leith, C. K., Pre-Cambrian geology: U. S. Geol. Survey Bull. 360, 1909.
Winchell, A. N., Mining districts of the Dillon Quadrangle: U. S. Geol. Survey Bull. 574, p. 29, 1914

These rocks are light-gray quartz-feldspar gneisses with subordinate hornblende and mica; hornblendic gneisses with minor amounts of feldspar and quartz; black amphibolite schists composed almost entirely of hornblende; white quartz-feldspar gneiss having the appearance of metamorphosed pegmatite; several narrow bands of dark hornblendic-garnet schist, and a few thin bands of mica schist. The reddish brown, gray and light gray gneisses of granitic composition are the most abundant.

This gneiss and schist complex is literally criss-crossed by igneous injections of both pre-Cambrian and later age. Rocks which have the appearance of metamorphosed granites associated with pegmatites and quartz veins are numerous. Basic gneisses of medium to coarsely-crystalline hornblende appear to have been originally sills and dikes of basalt or amphibolite. Many dark sills and dikes contain small lenses of feldspar oriented parallel to the prevailing schistose and gneissic structure. These are pre-Cambrian intrusives, but unlike the other gneisses and schists of igneous origin, they are probably post-Cherry Creek, since many of them cut both Pony and Cherry Creek rocks.

It is difficult to distinguish metamorphosed igneous rocks in the field. Indeed, some of these rocks are so similar to gneisses of sedimentary origin that it was impossible to differentiate them. For that reason they were not separately mapped. The mineral composition of many of these schists suggests an igneous origin. The lack of mica and quartz in many hornblendic varieties and the presence of abundant andesine feldspar give them the composition of metadiorite. Many of the quartz-feldspar-hornblende gneisses are probably metagranites. The quartz-mica schists, not abundant, may have been originally sediments. The lack of persistence of some of these rocks is indicative of igneous origin.

The Pony group is folded and faulted in a complex manner. Schistose and gneissic structures have been caused by the tremendous pressures which crumpled the rock into a plexus of great and minute contortions. The canyon of Madison River, east of Norris, exposes several miles of these contorted ancient rocks, offering an excellent opportunity to observe the complicated structure. The strike, measured on gneissic banding, changes from east-west near Mammoth, to about N. 45° W., near Norris. From Norris to McAllister the strikes swing gradually to north-south and near the latter village to N. 40° E. From McAllister to the Virginia City basalt a N. 40° E. strike is maintained with only a few exceptions.

Cherry Creek Series

In 1896, Peale[5] gave the name 'Cherry Creek' to a series of metamorphosed sediments well exposed in the vicinity of Cherry Creek, about 16 miles southeast of Virginia City. He considered these rocks to be of Algonkian (Preterozoic) age. Rocks belonging to this series are exposed over a large area in the Tobacco Root Range.

The type Cherry Creek section consists of quartz-feldspar gneiss, quartz-mica schist, crystalline limestone, quartzite, and hornblende-biotite schist.

The Cherry Creek rocks of the area included in this report are confined to the southern and southwestern portions, west of a line extending from a point several miles west of McAllister to Old Baldy, south of Virginia City, and east of a line including Wisconsin Creek and the Bismark mine, near the forks of South Boulder Creek. Sheridan is near the western limit and Virginia City, the eastern. The large quartz-monzonite intrusive limits the Cherry Creek on the north. South of Virginia City, these rocks form the western flank of the Gravelly Range.

The metamorphosed sediments of the Cherry Creek group differ markedly from the rocks of the Pony group. The Cherry Creek series consists of quartzites, limestones, schists, and gneisses whose sedimentary origin is unquestionable, whereas the Pony group possesses features common to both sedimentary and igneous rocks. No limestone or true quartzite occurs in the Pony group. Its structure and mineral composition are more complex and its origin more obscure than is the case with Cherry Creek rocks. The Cherry Creek rocks of this area include members with very high garnet content. Garnet is comparatively rare in the Pony rocks.

5. Peale, A. C., U. S. Geol. Survey Geol. Atlas, Three Forks folio (No. 24), 1896.

Although differences are apparent the similarities between the Cherry Creek rocks of the Virginia City-Sheridan area and those of the type locality on Cherry Creek, are striking. The great body of quartz-feldspar gneiss is almost identical in both. The limestones of one area could not be distinguished from those of the other. Quartzites are present in both, but more abundantly near Cherry Creek, and entirely lacking in some portions of the Virginia City-Sheridan area. Black hornblende-mica schists are present in both areas, but more abundantly at Cherry Creek. The principal difference is in the great abundance of garnet rock in the Tobacco Root region, a rock that is rare near Cherry Creek. This difference, however, will be explained later.

No unconformity has been found between the Pony and Cherry Creek groups. However, several lines of evidence point to the existence of such a stratigraphic break. In several places boulders were seen which contain unoriented inclusions of gneiss lying in a gneissic or schistose matrix. The best example of this feature is a large boulder, about 15 feet in diameter, in the South Boulder Creek valley, about 3 miles above the Mammoth mine. (See pl. 3, B.) An angular fragment of gneiss, about 2 feet across, is surrounded by a matrix of schist. The inclusion is a gneiss composed of quartz, feldspar, hornblende, and a little biotite. Its banding lies at a sharp angle to that of the inclosing quartz-biotite schist. This relationship suggests two periods of pre-Beltian metamorphism. It also suggests that when a gneiss is once formed it is stable in subsequent metamorphic activity. Boulders exhibiting unoriented inclusions of gneiss in gneiss or in schist were seen on Wisconsin Creek near Leiterville and near the Lakeshore mines, in North Meadow Creek near the Missouri mill, and in upper North Meadow Creek near the Frisbie mine.

The Pony gneisses and schists originated in part from igneous rocks. On the road between Ennis and Virginia City, numerous exposures of schist cut by gneissic granite and pegmatite occur in road cuts. The only pre-Cambrian intrusives which cut Cherry Creek rocks are basic dikes. This fact indicates that intense igneous activity occurred in the Pony series before the deposition of Cherry Creek.

It is probable, then, that folding, metamorphism, and igneous activity had occurred in the rocks of the Pony series before the Cherry Creek was deposited. Thus they must be separated by an unconformity. The evidence of an unconformity has been largely obscured by the intensity of metamorphism and the complexity of the Cherry Creek folding.

There are several lithologic units in the Cherry Creek series: a lower division made up largely of garnetiferous schists and gneisses; a middle division, dominantly limestone with varying amounts of quartzite and mica schists; and an upper division, composed chiefly of feldspar-quartz gneiss and quartz-mica schists. The garnetiferous rocks are dark brown or black on the fresh surface, weathering to a reddish brown. The color depends on the relative proportions of garnet and hornblende in the rock. The garnets attain diameters of four inches on upper Indian and Wisconsin creeks.

The crystalline limestone usually forms a relatively conspicuous exposure because of its light reddish-brown color and peculiar velvety sheen. On the fresh surface it varies from pure white or cream to dark gray or greenish blue. Tiny flakes of graphite are irregularly scattered through much of the limestone. The thickness of the limestone varies considerably according to the structural conditions. It is as much as 1,500 feet wide where thickened by folding, and in extreme cases it pinches out entirely, where it has been stretched on the limbs of folds. (See Rock structure, p. 41.)

The upper division appears to be the thickest of the Cherry Creek series. (The intense folding of the rocks makes estimates of thickness difficult.) The quartz-mica schist appears light gray on the weathered surface. It is composed chiefly of quartz and biotite with small amounts of hornblende and feldspar. Banding is well defined. The feldspar-quartz gneiss is a buff-weathering rock, massive and resistant, forming prominent outcrops, often the backbone of ridges.

A progressive change occurs in the Cherry Creek rocks from the south, near Virginia City, to the north, in the area of the headwaters of Wisconsin, Indian, and Mill creeks. The change is probably due in part to contact metamorphism. Certain members of the series, originally highly calcareous, have been partially or wholly replaced by so-called 'contact' minerals, most commonly garnet and hornblende. In lesser amounts tremolite, actinolite, epidote, and quartz, have been produced. The proportion of these constituents increases northward. Indeed, in some places, the rocks are almost entirely composed of garnet, or garnet and hornblende.

The change produced in the Cherry Creek, by more intense metamorphism partly due to proximity to the Tobacco Root batholith, involving the formation of an abundance of garnet, constitutes the principle difference between the rocks of the type locality at Cherry Creek and those of the Virginia City-Sheridan area. It is significant that this difference is more marked near the batholith and less marked at a distance from it, south of Alder and Virginia City.

An excellent exposure of Cherry Creek formations occurs near the road northeast of Laurin. Crossing the strike of the rocks from west to east are about 2,000 feet (horizontal distances) of crystalline limestone, 600 to 800 feet of hornblende gneiss with garnets, 300 to 500 feet of crystalline limestone, and about 2,000 feet of quartzite and quartz-feldspar gneiss. The distances are measured across the outcrop, and therefore do not represent actual thicknesses. Also the rocks are folded, thus causing repetition in the limestone, the quartzite, and the quartz-feldspar gneiss. Dips vary from 40° to 80° westerly. The true thicknesses are approximately 1,000 feet of limestone, 400 feet of hornblende gneiss, 200 feet of limestone (a second limestone member), and at least 800 feet of quartzite and quartz-feldspar gneiss.

Although not exposed in the Laurin section the garnet-hornblende gneiss lies beneath limestone in most places. It is well exposed in the walls of a canyon near South Meadow Creek about three miles southwest of McAllister. Here it is possible to infer the original sedimentary rock types. Thin beds of garnet rock and narrow lenses of quartzite alternate with thick layers of garnet-hornblende gneiss with subordinate feldspar and quartz, in which the relative amounts of garnet and hornblende vary through a wide range. A high proportion of garnet probably indicates a former calcareous rock (impure limestone, calcareous sandstone, or calcareous shale). It appears that the original formation was made up of a thick series of calcareous sandstones and calcareous shales with occasional beds and lenses of pure limestone and sandstone.

Thin mica schist and quartzite lenses sometimes occur closely associated with crystalline limestone. They were originaloy sand and shale deposited under local favorable conditions. They are thicker and more abundant in the southern part of the area, often entirely lacking in the north. In the original Cherry Creek locality these rocks make up a very large proportion of the series.

The third member of the Cherry Creek series, varying from feldspar-quartz gneiss with minor amounts of hornblende and mica to quartz-mica schist, probably represents metamorphosed arkose and impure sandstone. Its contacts with quartzite and limestone are concordant; no cross-cutting relationships or metamorphic effects were observed.

Summarizing the original character of the Cherry Creek, from an interpretation of the metamorphosed rocks, there was first a great series of calcareous shales with intercalated layers of sandstone and impure limestone; second, a thick limestone member, or in some places two neighboring members, of limestone, with interbedded lenses of shale and sandstone; and third, a great thickness of arkose, shale,and sandstone. As the top of the Cherry Creek series was eroded away before the Paleozoic deposition began, the total thickness and the character of the upper portion are unknown.

BELT SERIES

Rocks of the Belt Series[6] are found only in the north and northwestern parts of these mountains. The rocks are unusual lithologically, and are unlike the Belt formations in the typical areas northwestward. Furthermore, in this area the Belt is unusual structurally because strata of this age, 5,000 feet or more in thickness, thin southward and eastward, and within 15 miles are absent between the Paleozoic rocks and the crystalline gneisses. The thinning is believed to be due mainly to shore-line conditions during deposition.

In Jefferson Canyon (10 miles north of the area shown on plate 1) several thousand feet of pre-Cambrian rocks, believed to be upper Belt, are exposed along the highway. They consist of massive beds of conglomeratic quartzite and arkose. The pebbles of the conglomerate may be a foot or more in diameter, and are crystalline limestone, quartzite, gneiss, and pegmatite. In places the mass appears unsorted, but in general, bedding is quite evident. At the Mayflower mine a great thickness of gray-green

6 Clapp, C. H., and Deiss, C. F., Correlation of Montana Algonkian formations: Geol. Soc. America Bull. vol. 42, pp. 673-696, 1931; Mont. Bur. Mines and Geology, Reprint no. 1, 1931.

arkose underlies the Cambrian concordantly. In places the material contains coarse and more or less angular pebbles of milky quartz and gneiss, which may be an inch or more in diameter. Fragments of mica-schist were observed. At Renova Hot Springs the Cambrian formations are underlain, concordantly, first by about 300 feet of fine-grained, light-gray, dark-gray, and greenish shale, and then by relatively fine-grained greenish-gray arkose of great thickness. Mica is plentiful. Arkose is also present in the hills west of North Boulder Creek (off map).

Westward from Jefferson Canyon the rock becomes finer grained. Near Whitehall, pre-Cambrian rock which in hand specimens appears to be shale, by microscopic examination proved to be essentially arkose.

The Gold Hill mine, about 2 miles east of Renova Hot Springs, is in arkose.

PALEOZOIC FORMATIONS

In the Tobacco Root Mountains, Paleozoic sediments are found only in the northern and northwestern parts of the mountains, and beyond the southern limits of the mountains south of Virginia City. In the northern area the beds stand at steep angles in sharp folds, some of which are greatly modified by intense faulting. In the northwestern area, along the mountain front, the beds are steeply inclined toward the valley, but mountainward, as in Goodrich Gulch, the beds lie more nearly horizontal. Here also faulting has greatly disturbed the strata. The Paleozoic formations are essentially dense or crystalline limestone, but at the top and bottom are alternating beds of sandstone (or quartzite) and shale.

The Flathead quartzite, basal member of the series, is a conspicuous marker, and invariably stands up in bold outcrops. The rock is pinkish, compact, and brittle. As seen through a microscope in thin section, the rock is a mozaic of quartz grains cemented with silica. Locally bands of angular or rounded milky quartz pebbles occur near the base. The Flathead shale is greenish and very thin bedded. The ore deposits of the Mayflower mine are closely associated with this shale formation. Several hundred feet of Cambrian limestone lie above the shale, the most conspicuous member being a mottled dark and light gray magnesian limestone in the Gallatin formation.

Above the Gallatin is the Jefferson limestone and dolomite, characterized by the black color of certain members and the fetid odor of some beds when the rock is freshly broken. Above the Jefferson are the Three Forks shale and the conspicuous "mountain forming" Madison limestone. The limestone is white and massive and forms vertical cliffs. Fossil forms of brachiopods, bryozoa, and other invertebrates are plentiful in the Madison, but they seldom weather free from the enclosing matrix.

The Quadrant formation above the Madison is essentially alternating members of sandstone (quartzite) and shale. A reddish shale sometimes occurs near the base. The Phosphoria formation above the Quadrant, difficult to recognize, contains zones of oolitic "phosphate rock" which weathers to a steel-gray color; whitened angular fratments of this material betray the presence of the formation.

Ordovician and Silurian strata have not been recognized and are believed to be absent; however, the beds of the Devonian lie parallel to beds of Cambrian, and physical evidence of unconformity is lacking.

MESOZOIC

Above the Paleozoic (just above the phosphate beds) are approximately 3,000 feet of Mesozoic sedimentary strata, and then 2,000 feet or more of agglomerates and lavas of upper Cretaceous (upper Mesozoic) age. These rocks lie approximately parallel to the underlying Paleozoic, and are found only in down-folded or down-faulted areas where erosion has not cut deeply enough to remove them.

The Triassic, lowermost Mesozoic, is missing. The Jurassic may be recognized by the presence of fossil oyster remains. The Morrison is probably represented by a series of variegated shales. The Kootenai (or Dakota) is recognized by the presence of red-beds and massive sandstone members less cemented than those of the Quadrant. A limestone about the middle of the Kootenai contains abundant fossil gastropods (snail-like forms). Above the Kootenai is fine-grained, soft, dark, marine shale of the Colorado, unlike other shales in this district. Locally above the Colorado are alternating sandstone and shale beds of the Montana group, which contain imprints of leaves.

The agglomerate and lava series is particularly noteworthy, and no doubt, is the westward representative of the Livingston formation. The lavas are basic, basalt and andesite being most common. Certain of the lavas have platy white feldspar crystals oriented more or less parallel in a brown matrix, to which the descriptive name of 'oatmeal rock' is sometimes applied. The agglomerates are made up of somewhat rounded pebbles, composed of basic lava, in a matrix of basic lava, sand, or mud. Pebbles may be a foot or more in diameter. This group of rocks lies parallel to other Cretaceous strata, and they are involved in the intense deformation, both folding and faulting, of the Rocky Mountain uplift.

The best exposure of these rocks is along the lower portion of South Boulder Creek. They are faulted against Paleozoic and Belt at the Mayflower mine.

CENOZOIC

Cenozoic strata lie above older rocks discordantly. In the Tobacco Root Mountain area they are essentially lake beds, alluvial fan material, stream gravel and sand, and glacial debris.

The lake beds, which correlate with the Bozeman lake beds, are white, soft, earthy, and well stratified. Occasional beds of sand and gravel occur with finer material. Much of the fine material is volcanic ash either fresh or decomposed. Near Whitehall, teeth and bones of Oligocene or Miocene mammals are irregularly distributed through it. In the Tobacco Root Mountains lake beds may be seen northeast of Renova Hot Springs, near Harrison, and on both sides of the Ruby valley above Laurin. They occur elsewhere, and in places are gently tilted. East of Virginia City, 20 to 50 feet of white claylike material, probably at one time volcanic ash, underlies the basalt flows.

The alluvial fan material, lying over the lake beds, is composed of stratified, coarse fragments, outwash from nearby streams. Fans are best developed on the west side of the range.

The pebbles of the river gravel are generally well rounded, and consist of various kinds of rocks such as may be found in the headwaters of the stream by which they have been deposited.

IGNEOUS ROCKS

The effects of igneous activity in the Tobacco Root Mountains are widespread and varied. The earliest evidence of vulcanism occurs in the igneous gneisses of the Pony group, represented by the injection of both basic and acidic (granitic and basaltic) magma. The intrusion of a quartz-monzonite ('granite') batholith with its accompanying dikes and sills, in late Cretaceous or early Tertiary times, was the most important igneous event in the geologic history of the region. Soon followed the extrusion from Tertiary volcanoes, or vents, of sheets of andesitic, rhyolitic, and basaltic lavas. Interspersed with the effusion of lava was the ejection of great quantities of volcanic ash and dust into the air to be carried by the winds and spread over the surface of the land.

Little is known about the pre-Beltian intrusives beyond the fact that metamorphosed igneous rocks occur in the Pony group. Since they were described in an earlier part of the report, they will not be considered further.

The Tobacco Root Batholith

The large body of quartz-monzonite, exposed over an area of about 100 square miles in the central portion of the range, appears to be a typical batholith. It is elongated in a northwesterly direction, extending from about 3 1/2 miles west of Madison River, between Norris and McAllister, to about a mile beyond South Boulder Creek near the Bismark mine. Outliers are distributed around it at numerous points: one, two miles west of Pony; another, about three miles south of Red Bluff; others, at the head of Branch Creek, and just north of Mill Creek 3 1/2 miles from Sheridan; several in Bear Gulch and Coal Creek canyon; one, near the mouth of Perry Canyon; one, just west of Copper Mountain near upper Bivin's Creek; and one near the Easton mine southwest of Virginia City. It is highly probable that these bodies have a sub-surface connection with the Tobacco Root batholith. The abundance of dikes, quartz veins, pegmatites and ore deposits, in the intervening area between these outliers suggests that quartz-monzonite lies at a comparatively shallow depth.

The western outliers (in Bear Gulch) are only about 7 miles from the eastern margin of the Boulder batholith (near Silver Star). The alluvium-filled Jefferson valley separates the two igneous masses. The similarity of the rocks of both batholiths suggests that they are connected belew the surface. The age of the Tobacco Root mass is assumed therefore to be the same as that of the Boulder batholith: late Cretaceous or early Eocene,[7] intruded during the later stages of the Laramide Revolution, when high mountain ranges were formed in western North and South America.

The main mass of the batholith is a quartz monzonite, a medium-grained rock containing about equal proportions of quartz, orthoclase, and plagioclase, with hornblende or biotite. It differs from a true granite in the larger proportion of plagioclase feldspar. It grades into true granite in some localities. Different phases of quartz monzonite are due to variations in the amount of hornblende, biotite, muscovite, and augite.

A specimen from about a quarter of a mile east of the Garnet mine, west of Pony, is typical of much of the quartz monzonite. It has a pale pinkish color, which is slightly more pronounced on a weathered surface and has an even, medium-grained texture. The constituent minerals are quartz, orthoclase, oligoclase-andesine, hornblende, and a small amount of biotite. Apatite is the most common accessory mineral. This, with some variation in color, is apparently the most common phase in the batholith.

Dark colored basic rocks are relatively rare within the area of the batholith. They occur around the margins of the quartz monzonite, frequently forming a narrow border zone between it and the country rock. This zone usually merges by gradation in mineral composition into typical quartz monzonite.

North of Norris, near Norwegian Creek, the outer edge of the intrusion is a diorite, somewhat darker than the normal type, which grades into ordinary quartz monzonite within a few hundred feet. The dioritic border zone follows the contact all the way to Norris. Between Norwegian Creek and Norris lies a conical hill, locally known as Maltby's Mound, a monadnock of quartz monzonite, rising about 300 feet above the old erosion surface. The contact lies quite close to the road, and the dark dioritic border phase passes to quartz monzonite, of which the mound is composed, within about a quarter of a mile.

On the road-cut of the main highway, about 5 miles north of McAllister, a meladiorite (a diorite with an unusually large amount of dark mineral) is exposed. Within about 300 feet almost every gradation can be found between this rock and the normal quartz monzonite.

The different phases are generally found as segregated masses (schlieren) which may show sharp contacts. However, within a few dozen feet the same rocks may be seen to grade into each other. A specimen of the metadiorite has the following minerals in order of abundance: hornblende, biotite, and andesine, and these are estimated to compose 95 per cent of the rock. In addition there are magnetite, apatite and chlorite. Hornblende is a greenish brown variety having the characteristic prismatic cleavage. Biotite occurs in dark brown flakes some of which have their own crystal boundaries. Andesine is well twinned, shows considerable alteration to white mica, and almost all individuals show marked zonal banding. Another specimen collected within a hundred feet of this is a typical diorite. The texture is essentially the same but the color is much lighter. The chief constituents are oligoclase feldspar and hornblende. There is some biotite, a very little quartz and orthoclase. Magnetite and apatite are present but in much smaller amounts.

Rocks very similar to the above occur at several points around the margin of the intrusive. On the north side of Cataract Creek, about 1 1/2 miles west of Pony, is an outcrop of rock about 200 feet in diameter which might be called a melagranodiorite. Megascopically it is a medium-grained, even-textured rock in which hornblende and feldspar crystals attain lengths of one quarter of an inch, though occasionally individual hornblende crystals a half an inch in length may be found. The mineral constituents determined by microscopic examination are: hornblende (55%), andesine (25%), quartz (10%), orthoclase (5%), biotite (4%). Accessory constituents are apatite and magnetite. The microscopic texture is hypautomorphic granular, a texture in which some of the rock minerals have assumed their own crystal form upon solidification while others have crystallized in the intervening spaces and do not show crystal boundaries.

7: Billingsley, Paul, and Grimes, J. A., Ore Deposits of the Boulder batholith; Trans. Am. Inst. Min. Eng., vol. 58, p. 278, 1918.

Dioritic rocks also occur at the head of North Meadow Creek and at the head of the north fork of Mill Creek, and on Bear Gulch. Acid phases of the intrusion are common. A large irregular body of alaskite forms the country rock for the tungsten deposits of the Potosi district.

An elongated body of altered aplite passes through the Atlantic and Pacific claims west of Pony. It is several miles long and several thousand feet wide. Under the microscope it is seen to contain quartz, kaolin, sericite, and pyrite. The sericite appears to be the result of the alteration of feldspar, probably orthoclase. A fine grained interlocking mosaic of secondary quartz is molded around altered remnants of early minerals. Tiny, perfect crystals of pyrite are widely distributed.

Inclusions of a dark gray, basic dioritic rock are common in the granite of the Boulder batholith and are mentioned in descriptions by Winchell, Billingsley and Grimes, and Weed. This granite is used in Butte as building stone and many blocks show such inclusions. They may be seen in the steps of the main building at the Montana School of Mines. Inclusions of the same type are locally common in the Tobacco Root batholith. They vary in size from an inch to three or four feet, are rounded or subangular in form, and resist weathering to a greater degree than the inclosing granite, so that they frequently form rough projections on the surface. They are larger and more numerous near the margin of the intrusive. In color they are dark gray, and although the texture varies somewhat, the composition seems to be consistently that of a diorite. Corresponding to the rock found around the edge of the batholith. They undoubtedly represent cognate xenoliths, or blocks of the earlier-formed dioritic phase, which after solidification, was broken, the fragments having been incorporated as inclusions in the parent magma from which it originally separated. Xenoliths, or fragments torn from the invaded rocks, also occur, but these are definitely gneisses or schists, in which banding is still plainly visible.

An outlier of the batholith, a little less than a square mile in area, occurs 2 1/2 miles northwest of Pony. The mass is a diorite, fairly uniform in composition, but variable in texture. It is a dark gray rock with feldspar and hornblende as the chief constituents, individual crystals averaging

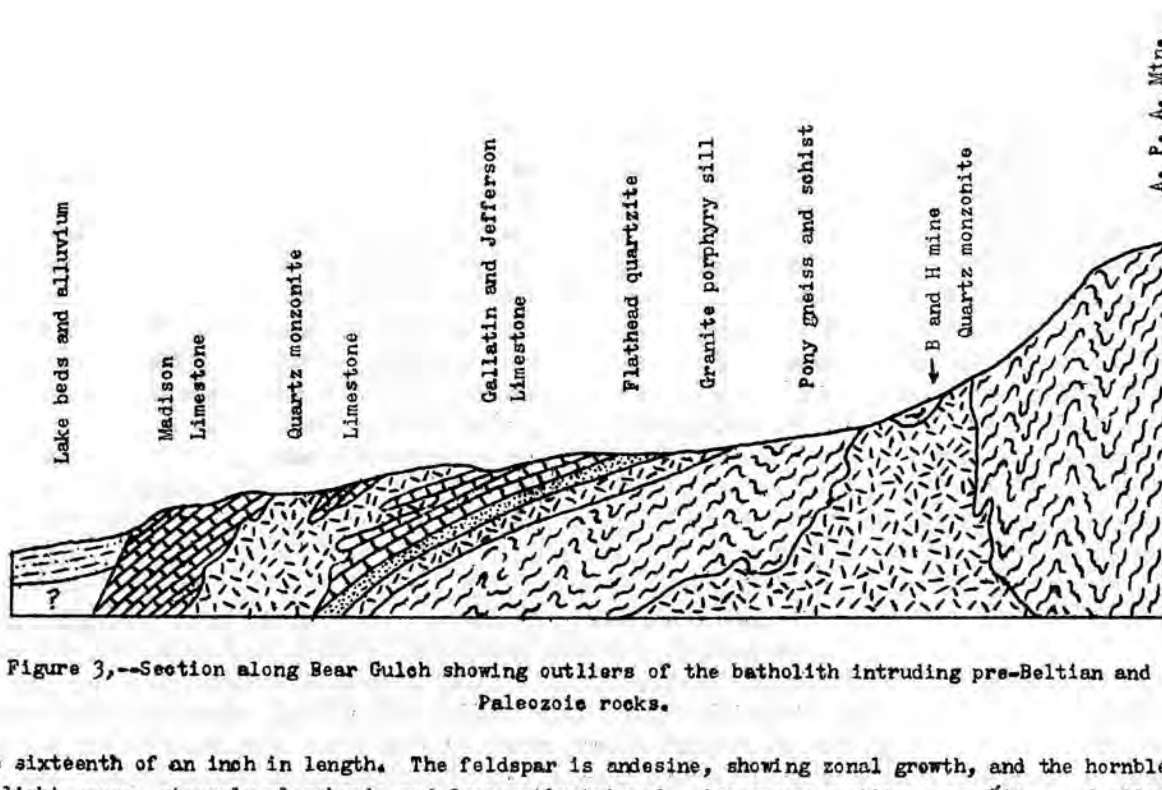

Figure 3,--Section along Bear Gulch showing outliers of the batholith intruding pre-Beltian and Paleozoic rocks.

one sixteenth of an inch in length. The feldspar is andesine, showing zonal growth, and the hornblende is light green, strongly pleochroic and frequently twinned. Accessory apatite, magnetite, and titanite make up about 5 per cent of the rock. On the divide between Charcoal Creek and Pony Creek, in the southeast quarter of section 10, T. 2 S., R. 3 W., where a tongue extends into the gneiss, hornblende crystals are arranged in roughly parallel orientation. It is likely that the constrained magma crystallized under directive stresses and that the hornblende became oriented in the direction of least pressure. On the highway 4 1/2 miles south of Alder there is an intrusion too small to appear on the map, which on microscopic examination is found to be an alaskite. Megascopically it is a fine grained, light-colored, even-textured granitic looking rock. Examination in thin section shows it to contain microcline (45%), albite (15%), orthoclase (7%), quartz (30%), biotite (2%), accessory apatite and secondary mica (1%).

Rocks of other outlying masses were not examined under the microscope but are either dioritic, as the mass east of Sheridan, or granitic, as those of Red Bluff, North Meadow Creek, and Bear Gulch.

Dikes and Sills

Dikes and sills emanating from the granite are very numerous, but only a few of the more prominent ones have been mapped. Locally, over a small area, the ground is cut by innumerable granite pegmatite dikes; such a point is the divide between Barton and Alder gulches, east of the Barton Gulch mine. These are nearly white, coarsely crystalline, unfoliated rocks, composed almost entirely of quartz and feldspar. Many of the dikes contain fine intergrowths of quartz and feldspar producing a variety known as graphic granite. Microscopic measurements were made by the Rosiwal method, on two such specimens; one from a dike located about half a mile east of the Barton Gulch mine, and the other from a dike on the Mountain Flower claim of the Smith group, located about 7 miles southeast of Alder. In both specimens the composition was within one per cent of the calculated quartz-feldspar eutectic proportions, 28% quartz and 72% feldspar (microcline).

Quartz bodies occur abundantly as irregular masses, pipes or chimneys, and veins. In some, quartz is the sole constituent, but others, containing both quartz and potash feldspar, are true pegmatites. There are all gradations in a single vein from pure quartz to both quartz and feldspar varieties. The quartz is coarsely crystalline and white. In places feldspar crystals are a foot or more in length. Metallization rarely occurs in this type of quartz vein. These masses of quartz increase in number near the batholith.

The most prominent sill in the district can be seen for several miles, a broad reddish band passing over the top of Old Baldy Mountain on the north slope of Wisconsin Creek. It is well exposed on the steep southeast slope of the mountain where it is estimated to be about 300 feet thick, striking northeast and dipping westward. It generally occurs below the Flathead quartzite, which here is the earliest Paleozoic formations, but occasionally fragments of the Flathead formation are found at the bottom of the sill. The rock is a porphyry with phenocrysts of white feldspar varying from one eighth to three eights of an inch in length, and frequently showing twinning, embedded in a fine grained groundmass of reddish brown color. On a deeply weathered surface the whole rock takes on a more somber hue and the phenocrysts are difficult to distinguish. The reddish color is probably due to finely disseminated primary iron oxide. Under the microscope the texture is porphyritic holocrystalline. Large idiomorphic crystals of orthoclase are enclosed in a fine-textured groundmass of feldspar and quartz. The composition is orthoclase (59%), quartz (40%), the remainder being made up of accessory apatite, magnetite, hematite, pyrite, and secondary white mica. The rock is a granite porphyry.

From the divide separating the heads of Wisconsin and Dry Boulder creeks, a granodiorite porphyry dike can be traced eastward, with some interruptions, across Lakeshore Peak into the cirque at the head of South Boulder Creek. Megascopically, prominent phenocrysts of white plagioclase feldspar are seen to be enclosed by a greenish-gray fine-textured groundmass. Microscopic examination shows the material to be oligoclase (35%), orthoclase (15%), quartz (30%), biotite (5%), hornblende (10%), with accessory minerals apatite, magnetite, titanite, and pyrite, comprising the remaining five per cent. Oligoclase occurs as idiomorphic crystals with characteristic twinning and pronounced zoning, embedded in a groundmass of hypidiomorphic feldspar and interstitial quartz. The hornblende is the ordinary pale green variety showing slight alteration to chlorite.

Another granodiorite porphyry dike occurs on Ramshorn Creek above the Agitator claim and can be traced for about half a mile southwest to Coral Gulch. It is very similar in appearance to the previous dike except for sporadic quartz phenocrysts and tiny specks of pyrite which are visible with a hand lens. The dike is about 35 feet wide, nearly vertical, and strikes about N. 15° E. A similar, but smaller granodiorite dike, also vertical and striking about north-south, lies one mile southwest of the Smuggler mine, between Mill and Ramshorn creeks.

At the Mammoth property on South Boulder Creek, located about half a mile below the office buildings, is an interesting dike which contains pyrite and galena. It is grayish-black, fine-textured, traversed by many thread-like veinlets of calcite, and in the field somewhat resembles a diabase. Microscopic examination shows it to be a microgranite. The texture is much finer than an ordinary granite and the proportion of dark minerals, mostly biotite, is higher, but otherwise the composition is that of a granite.

At the Noble property, on Wisconsin Creek, two lithologically dissimilar dikes are closely associated. One is a granodiorite porphyry dike showing no unusual features, and the other is a much larger olivine gabbro dike which, in appearance, closely resembles the intrusive mass at the head of North Meadow Creek. The dikes are nearly parallel and strike northwest. The basic dike is a grayish-black, medium-textured rock containing diopside (30%), olivine (20%), biotite (10%), labradorite (30%), with accessory magnetite, and secondary magnetite and serpentine.

Near the crest of the range, between the headwaters of North and South Meadow creeks, is an andesite porphyry sill, varying in thickness from 20 to 75 feet, which intrudes schist and gneiss. It is well exposed on South Baldy Mountain, at the Missouri and McKee properties, and appears at several other points within a radius of 1 1/2 miles.

Small diabase dikes are numerous and may be found cutting the schists and gneisses in almost any locality. Some appear to be very old, as they are much recrystallized and folded along with the metamorphic rocks; others are quite fresh, traverse the schistose trends, and may be geologically very young, perhaps related to the Virginia City basalt. Though probably not more numerous, the basic dikes are in general more persistent than the acid varieties. Even when not actually outcropping they can frequently be traced by means of a reddish brown soil characteristic of their weathering.

On the north side of California Gulch, about 5 miles east of Laurin is a prominent dark greenish-gray dike varying in width from 100 to 200 feet and striking northwest. Approximately along the same strike a similar rock is found on Branch Creek and again on Ramshorn Creek. It seems to be the same dike traceable in this manner for over 7 miles. It is a quartz diabase in composition. The pyroxene is diopside, and the amount of quartz, chiefly contained in micropegmatitic intergrowths, is about five per cent. Another dike of the same character lies 1 1/2 miles to the west of it on California Gulch and less than half a mile from it on Ramshorn Gulch. The normal variety of quartz-free diabase also occurs. These are dark green to grayish-black holocrystalline rocks varying in texture from fine to medium grain, the finer grained phases, in general, occurring in the smaller dikes. On Dry Boulder there are numerous diabase dikes, cut by equally numerous pegmatite dikes.

At the head of North Meadow Creek there is a sill-like intrusive body of dark basic-looking rock which outcrops over an area of about three quarters of a square mile. There are olivine bearing and olivine free phases; in some parts the dominant pyroxene is hypersthene, and the feldspar labradorite, the rock grading into a norite; at other points the pyroxene is diopside and the feldspar less basic, so that the rock is a basic diorite. The mass is cut by acid dikes, one of which, a granodiorite in composition, outcrops on the steep hillside half a mile southeast of the camp buildings at the Frisbie mine.

A most interesting and unusual rock, too small in textent to be shown on the map, occurs on the north side of Copper Mountain, about 8 miles southeast of Sheridan. It is surrounded by schist and gneiss and forms no prominent outcrops but disintegrates readily into reddish brown fragments. In a hand specimen the only recognizable mineral is a deep red variety of garnet which occurs in rounded grains generally less than one sixteenth of an inch in diameter. Examination in thin section shows the constituents to be garnet (45%), omphacite (40%), quartz (10%), and magnetite (5%). The garnets appear as rhombic dodecahedrons, fresh and unaltered, with well rounded edges. Omphacite is a grass-green variety of augite which occurs only in a rather rare rock called eclogite. In the thin section examined it appears quite fresh and contains numerous inclusions of quartz, garnet, and magnetite. Magnetite occurs as idiomorphic crystals and also as narrow streaks along cleavage lines in the omphacite. The minerals show a tendency toward elongation in one direction, probably the result of stresses during crystallization. The order of crystallization has been magnetite, garnet, omphacite, and lastly quartz which is entirely xenomorphic and merely fills the interstitial spaces.

The term eclogite was first used by the French petrographer Hauy more than a century ago, to designate a rock composed chiefly of green augite and garnets. Geologists are not entirely agreed as to the derivation of eclogite, but the general opinion seems to be that it is formed from a basic eruptive of the gabbro type. So far as the writer is aware the only other rocks in the United States described as eclogite occur in California.[8]

Extrusive Rocks

Extrusive rocks found in the area consist of andesite, rhyolite, basalt, and volcanic ash.

Of these the basalt, a heavy, fine-grained dark rock composed chiefly of plagioclase feldspar and pyroxene, has by far the largest areal distribution. It came up through fissures in the earth's crust and poured over the surrounding country as lava. In this area the largest mass occupies about 50 square miles east of Virginia City. It is composed of many separate flows, having an aggregate thickness of well over a thousand feet, though it becomes thinner toward the north, and it is impossible to say just how much more has been removed by erosion. Near Norris there is a remnant of a basalt flow about half a square mile in area, approximately 300 feet thick, and dipping northward at about 6°. Similar rocks occur near Red Bluff. A small patch of basalt, overlying lake bed material, on Williams Gulch, southwest of Alder, was probably once continuous with the larger mass east of Alder Gulch. Two small patches of basalt were found on Horse Creek 13 miles northwest of Virginia City. The basalt once covered a much larger area than at present but has since been partly removed by erosion. Since it is younger than the lake beds, it was probably extruded in Pliocene or early Pleistocene time.

A small outcrop of andesite occurs about one mile north of Virginia City. It is composed chiefly of plagioclase and biotite as phenocrysts less than one sixteenth of an inch long embedded in a fine-textured dull gray matrix. The stone has been quarried and used for buildings in Virginia City, one of the most pleasing of which is the Virginia City museum.

Rhyolite lava occurs in small isolated patches south of Red Bluff and north of McAllister. It is gray or purplish gray and so fine textured that the constituent minerals cannot be recognized except by microscopic examination. About 3 miles from McAllister, up North Meadow Creek, is an exposure of rhyolite in which flow banding is so perfectly developed that it may easily be mistaken for bedding; in fact, the place is locally known as Slate Point because of its superficial resemblance to gray slate. Rhyolite is exposed for 500 feet along the roadway on the west side of the creek. On the east side of the creek is a smaller exposure of the same rock, but more massive, with only a trace of flow banding. All gradations from a massive rhyolite, through thinly banded rhyolite, to a vesicular variety at the top of the section, can be found.

Volcanic ash and tuff are interstratified with sedimentary beds of Cretaceous age on South Boulder Creek. Tuff also is very common in the Bozeman lake beds. However, the most interesting occurrence is a bed of volcanic dust from 6 to 12 inches thick which has been exposed by placer workings on Norwegian Creek. It is an ashy-gray, fine-textured, powdery material, in fact, so fine that practically all of it will pass through a 100-mesh screen. It is composed of tiny particles of glass which are rod-like, sharply angular, or scalloped in outline when viewed under the microscope. It lies but 5 or 6 feet below the present surface, and though volcanic material was not noticed elsewhere in this position, according to Mr. Alexander Leggat[9]. of Butte there are similar occurrences near Butte. This most recent expression

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8. Holway, R. S., Eclogites in California: Jour. Geol., Vol. XII, pp. 344-358, 1904.

9. Personal communication.

of volcanic activity, but a few hundred years old, was probably carried by winds from the southwest. The uniform fineness of the material indicates that deposition took place at a considerable distance from its source. Other volcanic ash beds in Montana are described by Rowe.[10]

ROCK STRUCTURE

From the standpoint of structure, the rocks of the Tobacco Root Mountains must be considered in the light of several successive periods of mountain-building movements, each period imprinting its structural pattern on all pre-existing rocks. Thus, the Paleozoic and Mesozoic rocks are crumpled and broken by the late Cretaceous deforming forces; pre-Beltian rocks of the district bear the scars of several successive deformative stages, giving them an extremely complicated structural pattern. The younger rocks, deformed by only one major earth disturbance, possess relatively simple structure.

ROCKY MOUNTAIN DEFORMATION

Since the close of the period of Rocky Mountain deformation saw the intrusion of the mineral-bearing Tobacco Root batholith, the structural picture of the thick Paleozoic and Mesozoic roof of the batholith of that time takes on added interest. Although much of that early cover has been eroded away, enough remains around the margin of the mountains to give a fair opportunity to deduce its original position. In its broad features, the younger rocks were arched over the central part of the range in a broad assymmetrical dome, or doubly plunging anticline. The long axis of the dome, with a north-south trend, passes near the crest of the Gravelly Range in the south, and near Whitehall in the north. The gently dipping limbs (locally steepened) are all that remain today of the eroded structure. They are exposed on the north-west and north slopes of the range, on Old Baldy south of Virginia City, and east of Madison River. Projecting the formations upward, at the present angle of inclination, they would pass over the mountains a few thousand feet above the present surface. But actually their elevation was probably not more than a thousand feet above the crest of the range.

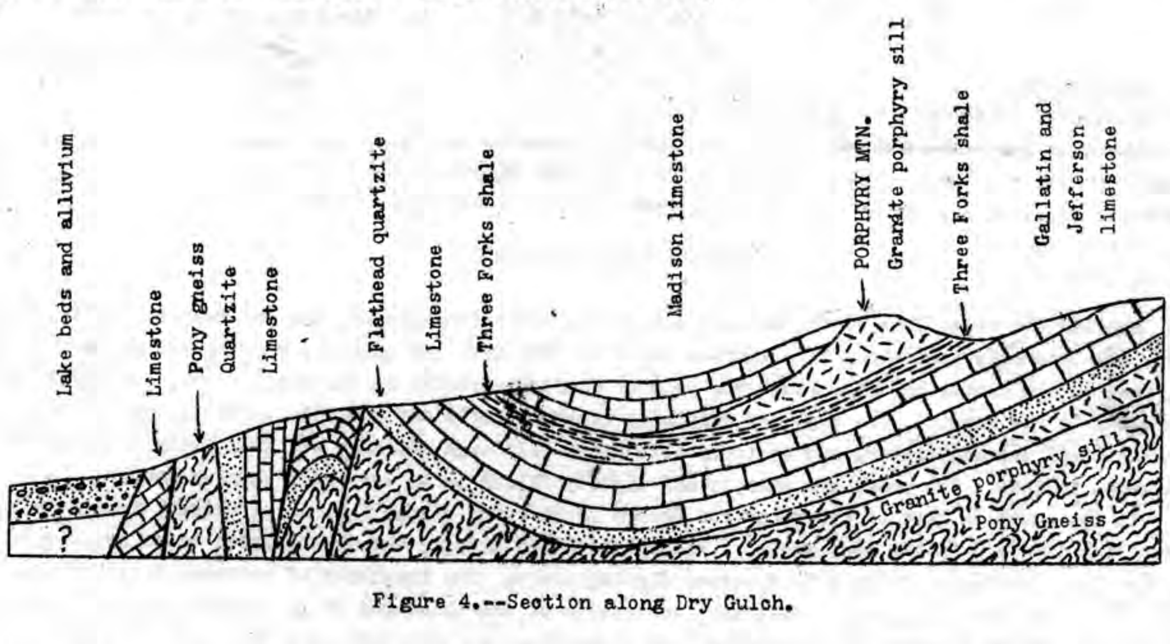


Figure 4.--Section along Dry Gulch.

From the structure of the Paleozoic and Mesozoic rocks, north and south of the mountains, it is evident that the batholithic cover was not a simple elongated dome, but was one with minor troughs (synclines) and ridges (anticlines) superimposed upon it. A subordinate syncline passed over Virginia City,

10. Rowe, J. P., Some volcanic ash beds in Montana: Univ. Montana Bull. 17, Geol. Ser. 1, 1903.

Ramshorn Mountain, and lower South Boulder Creek; a subordinate anticline rose over the vicinity of Laurin, upper Indian Creek, and Renova Hot Springs. It is probable that other small structures were superimposed on the large structural dome.

That the domal structure was a locus of weakness which afforded to the batholithic magma access to the upper crust, cannot be positively stated. Yet the close association of such a structure with a large body of igneous rock suggests a genetic relationship.

The Paleozoic and Mesozoic rocks are complexly faulted in some places. In Dry Gulch excellent fault exposures show nearly vertical fault surfaces striking N. 20° - 40° W. (See fig. 4.) The faults are probably the result of the breaking of the crest of a sharp fold.

Another interesting group of faults occurs near Renova Hot Springs. They are nearly vertical and vary in strike from N. 45° E. to N. 68° E. These faults appear to be an adjustment of relatively brittle rock layers to the sharp folding of Paleozoic rocks around the northern nose of the Range--the broken apex of a subordinate fold on the major dome.

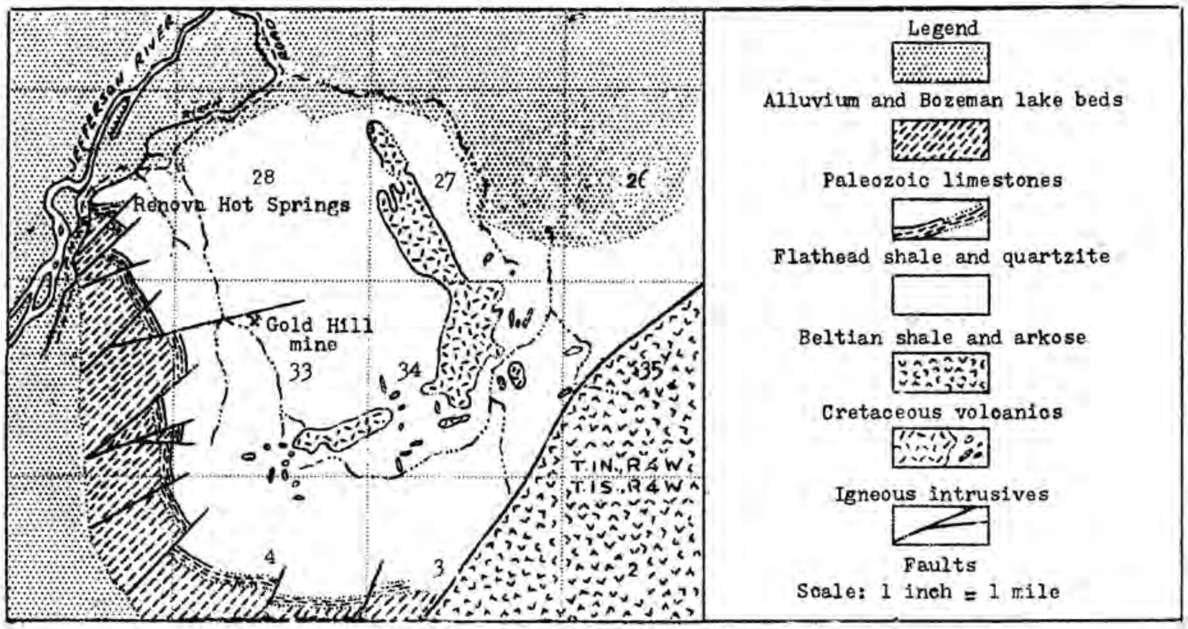


Figure 5.--Sketch map of faults south of Renova Hot Springs.
(Mapped by Dr. E. S. Perry and field class of 1933.)

PRE-BELTIAN STRUCTURE

Beneath the broad dome of the Paleozoic-Mesozoic batholithic cover, the pre-Beltian gneisses and schists are intensely contorted. The surface trend of schistose and gneissic banding swings in a great arch, open on the south, bending around the body of quartz-monzonite on the west, north, and east, roughly parallel to its margin. The dips are northerly between Norris and Mammoth, easterly and westerly between Red Bluff and McAllister, and westerly elsewhere. Although the dips are relatively uniform in a local area, in detail the rocks are sharply and tightly folded in an extremely complex manner.

In the southern part of the range the Cherry Creek rocks occupy a broad structural trough or synclinorium infolded in the Pony gneiss. Within the broad trough, the Cherry Creek rocks are highly contorted into overturned folds with westward dipping limbs. The constancy of westward dips between Virginia City and Sheridan gives a deceptive conception of the thickness of the Cherry Creek group, for, instead of one great westward dipping series, the formations are repeated again and again by folding (figs. 6 and 7).

The Cherry Creek limestone presents an extremely sinuous pattern on the geological map. This sharpness of curvature, however, is dependent on the pitch of folds (the angle of inclination of fold axes) and the configuration of the surface. Thus, a gently pitching fold presents a sharp curvature on the map; a steeply pitching fold, a gentler curvature. (See fig. 8.)

The Cherry Creek rocks in the north part of the Sheridan-Virginia City area appear to pitch gently southward. Those in the vicinity of Laurin and Horse Creek pitch north.

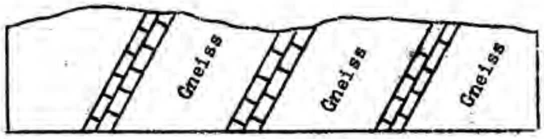


Figure 6.--Observed section of uniformly dipping formation with three limestone members.

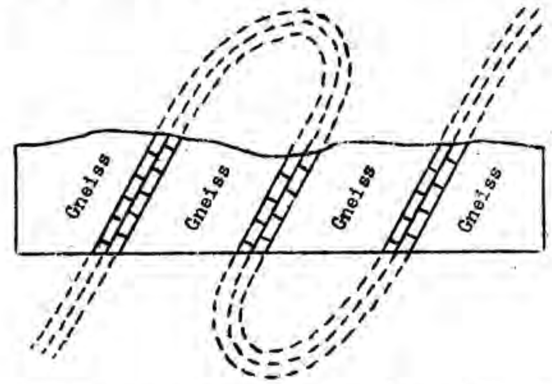


Figure 7.--Limestone of figure 6 explained by repetition due to close overturned folding.

An exception to the general, steeply-dipping, closely-folded structure is a zone between Ramshorn Mountain and the Missouri mill. Here, the Cherry Creek rocks are nearly horizontal, dipping gently eastward in the vicinity of South Baldy Mountain, increasing gradually in dip down the valley of South Meadow Creek, and finally overturning in the vicinity of the saw mill. About half a mile west of Ramshorn Mountain the horizontal formations are thrust up, along a gently eastward-dipping fault surface, over sharply folded Cherry Creek rocks. This thrust fault strikes northeast passing across the crest of the range between Fairweather Mountain and Belle Point.

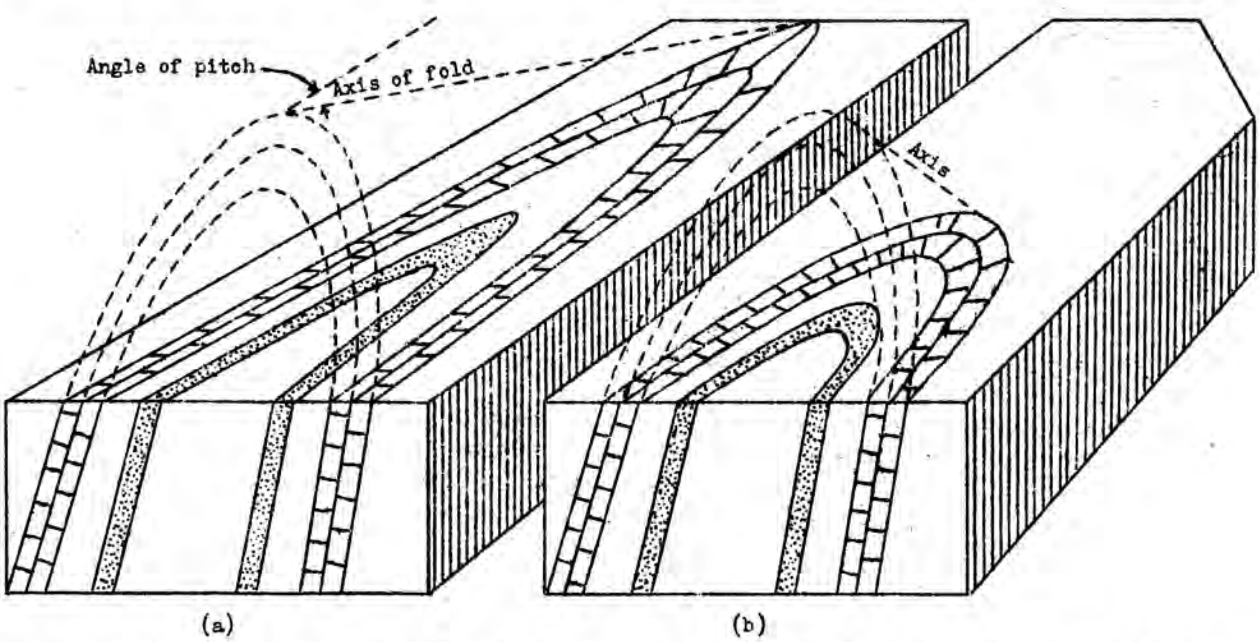


Figure 8.--Block diagrams showing the effect of the angle of pitch on the outcrop of a fold, (a) gentle pitch, and (b) steep pitch.

Other faults, apparently with small displacements, cross Ramshorn, Bivinc and California gulches with remarkable regularity in strike, (N. 20° - 30° W). They are probably not of pre-Beltian age since the trend is similar to later faults in Paleozoic and Mesozoic rocks.

TERTIARY DEFORMATION

The present topographic form is due largely to faulting and tilting which began in early Tertiary times and continued throughout the duration of that period. Indeed, spasmodic shifts along the old surface of fracture have occurred at intervals up to the present time.

This faulting uplifted some blocks and depressed others, producing structure and topography similar to that of the Basin and Range province of southwestern United States. The broad valleys of Jefferson, Madison, and Ruby rivers represent down dropped segments, the uplifted segments forming the bordering mountains.

Three normal faults striking about N. 25° W. cut off the southwestern face of the Tobacco Roots. They have dropped the segment on the southern side at least two thousand feet. The northwestern front of the range represents a fault face, the eastern margin of the depressed Jefferson valley segment. The broad valley of Madison River is abruptly terminated by a Tertiary fault which passes just north of Madison Lake and along the north wall of the lower part of the south Meadow Creek valley.

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

The metamorphic character and structural complexity of the Pony group obscure much of the record of of its history. That sedimentary rocks were folded, metamorphosed, and intruded by granite, diorite, basalt, and pegmatite, before the deposition of the Cherry Creek, there can be little doubt. The folded mountains of Pony rocks were eroded and depressed beneath the sea to receive the sedimentary detritus and limy muds which make up the Cherry Creek formations.

Another period of deformation crumpled the Cherry Creek beds, elevating them into mountains, exposing them to weathering and erosion. The land was again depressed and Belt sediments were deposited.

Paleozoic time found the Belt sedimentary rocks depressed to the sea floor. Intermittent uplift and depression brought about the accumulation and partial erosion of Paleozoic rocks, chiefly limestones.

Terrestrial deposits were laid down during the early part of the Mesozoic followed by marine (Ellis) sediments, and the final part of the era marked an alternation of marine and terrestrial conditions when thick deposits of sandstones and shales were formed.

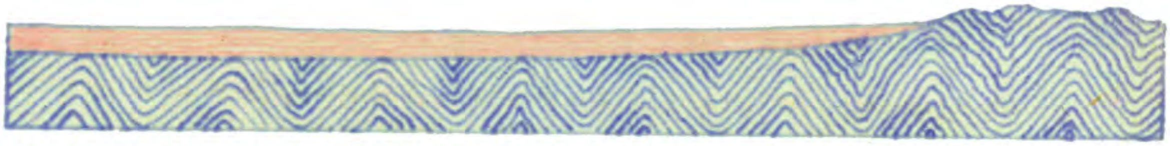
The Rocky Mountain folding, beginning in middle Cretaceous time (late Mesozoic), crumpled and faulted the rocks of the great Cordilleran region from Alaska to Cape Horn. Following the widespread orogenic movement, intrusion occurred, implacing the Tobacco Root batholith and many other Cordilleran igneous bodies. The intrusion occurred during late Cretaceous or early Tertiary (Eocene) time.

The mountain range produced by the late Mesozoic folding was eroded down to a region of low relief. The old Madison and Jefferson rivers flowed southward into Snake River. A great change in topography and drainage was brought about by a combination of faulting, warping, and extrusion of lava during Eocene and later times. River valleys were blocked by lava flows and fault-dams. Stream gradients were altered by warping.

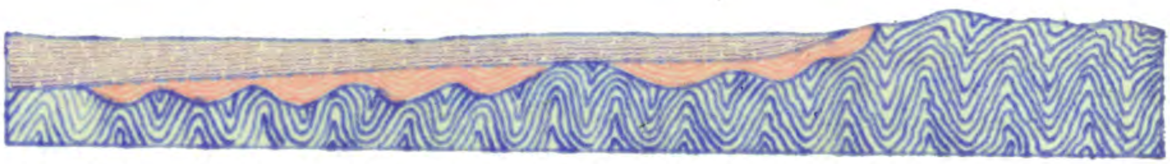
Water accumulated behind these dams, forming chains of large lakes. While faulting elevated segments of the crust into mountains, rejuvenated streams poured muds, sands, and gravel into the lakes. Distant volcanos blew great quantities of ash and dust into the air to be born into the lakes by winds, or washed down from the adjacent mountains. Finally outlets cut their channels deep into the dams, gradually lowering the lake levels, and at length, draining them. But the new rivers reversed the direction drainage in the main channels, and now flow into the Missouri instead of the Snake. The block-faulted mountains attainted considerable elevation and the present topographic appearance was achieved.

Pleistocene cold brought on glaciation; mountains became blanketed with huge sheets of moving ice, the margins and protruding tongues moving downward and melting back with fluctuations in temperature.

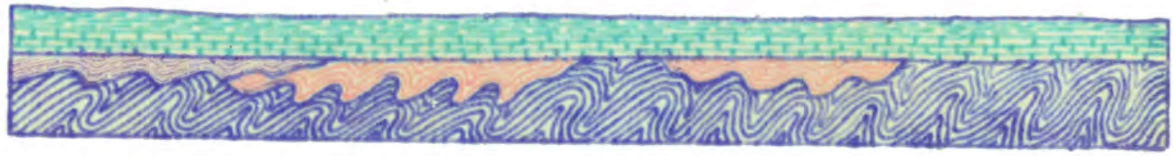
The present follows close on the heels of glaciation. The great ice masses have only recently left these mountains; vigorous stream erosion has only begun the task of removing the morainal evidences of glaciation.



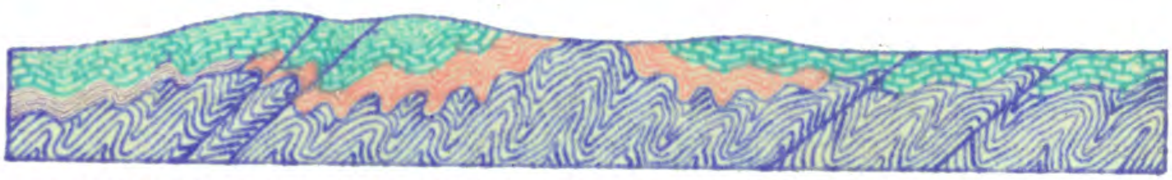
A. Pre-Beltian. Folded and eroded Pony series were depressed below sea level and the Cherry Creek sediments were deposited.



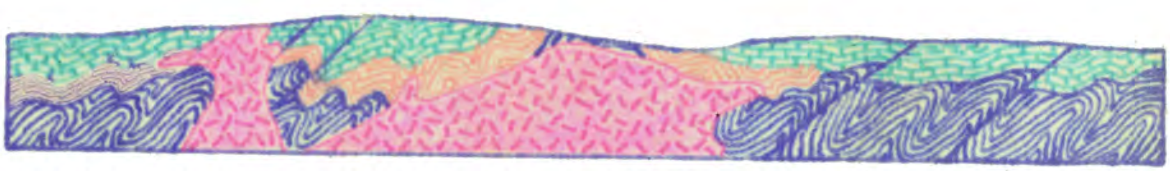
B. Beltian. Folding, elevation, and erosion preceded the deposition of the sediments of the Belt series. A near-by land mass to the east contributed these sediments.



C. Paleozoic--Mesozoic. The gently warped and eroded Belt rocks were depressed and a great thickness of Paleozoic and Mesozoic sediments was laid down.



D. Late Mesozoic (Cretaceous). Rocky mountain folding crumpled and faulted the rocks and elevated the surface, exposing it to vigorous erosion.



E. Late Cretaceous or Early Tertiary. Closely following folding, igneous rocks were intruded and the land surface was eroded to a nearly level plain.

F. Tertiary. Faulting and lava flows dammed the stream courses forming intermontane lakes in which the Bozeman lake beds accumulated. Continued faulting caused the elevation of large earth segments, and alluvial fans were built up at the foot of the slopes.

IDEALIZED SECTIONS ILLUSTRATING THE GEOLOGIC HISTORY OF THE TOBACCO ROOT MOUNTAINS.

PART II

ORE DEPOSITS

by

L. H. Hart

INTRODUCTION

For purposes of correlation and discussion the ore deposits of the major portion of the Tobacco Root Mountain area are divided into five regions: Pony, Twin Bridges, Sheridan, Virginia City, and Norris. Although individual maps of each of those districts have not been prepared, the general geological map of the Tobacco Root area shows the location of the more important mining properties and general trends of the major vein systems. In places it will be noted that general controlling features centering in one district may extend into adjoining areas, and for this reason the selection of definite regional boundaries is difficult.

The Tobacco Root area has been an important metal producer, the best estimate of the value of gold, silver, copper, lead, and zinc from lode mines totalling approximately $16,500,000, of which the major portion has been in gold. In addition to this, the value of the production of gold from alluvial deposits is estimated at $52,000,000 and may be more than that amount. Therefore, the total value of the metallic production is very nearly $70,000,000.

An area with such an important production record is certainly worthy of serious study relative to the possibilities of maintaining production in future years, and the data herein presented has been collected with the hope that it may be of value in furthering future activities.

ACKNOWLEDGMENTS

A list of the mine owners and operators who very generously assisted the field party to secure information in connection with this report is too long to include. The purpose and probable value of the study were generally recognized by all, and every possible assistance was freely extended. The writer wishes to express his sincerest thanks and appreciation to those so assisting, and hopes that in some measure, the information herein may repay them for their kindness.

PONY REGION

HISTORY AND PRODUCTION

The present report on the Pony region includes the Mineral Hill, Granite, Potosi, Mammoth, and Norwegian districts.

The Pony camp was established in the early '70's, somewhat later than the other districts in the Tobacco Root area. The silver mines of the Potosi district and the Clipper mine of Mineral Hill district became quite active during the '80's, and many other properties became important during the '90's.

The figures for the following table prior to 1913 were taken from United States Geological Survey Bulletin 574, and include production statistics for the Mineral Hill, Potosi, Sand Creek, and Norwegian districts. From 1913 to 1930 inclusive, the figures were compiled from 'Mineral Resources of the United States', published by the United States Geological Survey until 1923, and from that date on by the United States Bureau of Mines. The figures are by no means complete but include all available statistics for the region.

Mine production of gold, silver, copper, and lead in the Pony district, Montana, 1874 to 1930.

Year	Mines Reported	Ore	Gold	Silver	Copper	Lead	Total Value
		(short tons)		(fine ounces)	pounds	pounds	
1874 to 1880	---	4,000	------	------	------	------	$ 200,000
1881 to 1890	---	10,000	------	------	------	------	400,000
1891 to 1901	---	150,000	------	------	------	------	4,000,000
1902	---	1,575	$ 41,228	1,141	------	21,000	42,437
1903	---	685	13,719	600	------	25,000	14,532
1904	---	1,491	68,759	4,023	------	------	57,012
1905	---	16,936	89,331	4,356	3,205	65,326	96,480
1906	---	11,132	82,853	8,893	50,383	112.007	104,927
1907	---	4,924	52,540	4,325	28,580	7,500	65,513
1908	16	5,796	53,440	3,946	11,315	15,103	57,690
1909	19	7,474	88,547	3,891	9,925	1,145	91,917
1910	14	15,301	135,868	6,651	20,671	------	142,098
1911	9	15,386	83,921	5,606	8,545	8,021	83,328
1912	5	14,187	57,710	5,263	4,066	273	61,634
1913	9	7,320[a]	35,836[a]	2,061[a]	2,871[a]	4,395	37,720
1914	13	10,158[a]	41,614[a]	1,797[a]	2,671[a]	6,768	43,227
1915	12	10,282	90,906	3,848	5,265	------	93,778
1916	13	8,961[a]	44,165[a]	2,635[a]	3,751[a]	------	49,425
1917	12	2,640[a]	13,229[a]	951[a]	1,335[a]	2,732	17,099
1918	5	1,069	8,078	242	52	------	8,333
1919	2	(b)	(b)	------	------	------	(b)
1920	4	595[a]	5,019[a]	374[a]	------	------	5,427
1921	6	310[a]	2,547[ac]	113[a]	------	------	2,660
1922	1	(b)	(b)	------	------	------	(b)
1923	4	(b)	(b)	(b)	(b)	(b)	5,000
1924	5	66[a]	1,513[a]	91	371	(b)	1,623
1925	4	(b)	(b)	(b)	(b)	------	(b)
1926	11	64[a]	1,514[a]	221[a]	23	2,656[a]	4,572
1927	4	18,000[a]	(b)	(b)	(b)	------	125,000
1928	8	35,450	191,814	16,714	202,165	------	230,704
1929	4	32,000[a]	173,200[d]	(b)	(b)	------	173,200
1930	7	32,500[a]	202,900[a]	(b)	(b)	------	204,900
Totals		418,302					$6,420,236

(a) Figures incomplete, (b) Some production, amount not known, (c) Includes production from placers. (d) Estimated.

GEOLOGY

The major geological features of the Pony area are relatively simple in that the surface is occupied by only two important rock types: pre-Beltian metamorphic rocks of the Pony series, and a quartz monzonite (granite) intrusive. The granite occupies the southern portion of the area. Pegmatite dikes are common throughout the area of rocks of the Pony series, and as many of these are believed to be of late age, they probably represent offshoots from closely underlying granite bodies.

Large dike-like bodies of aplite are noted in several places at or near the contact of granite with metamorphic rocks, as at the Atlantic-Pacific mine. For a more complete consideration of the areal distribution of these rocks, the reader is referred to Part I of this report.

The contact between the two major types of rocks generally extends westerly and roughly divides the area into two geological units. The principal fissures are closely parallel to the contact and in general they conform, especially in strike, to the banding of the gneiss. These fissures are often strong and persistent as in the Mammoth, Clipper, Boss Tweed, and Strawberry groups, and although not always characteristically wide, are usually traceable for hundreds of feet and in some places, even for thousands of feet, as at the Mammoth mine.

The mineralization varies throughout the district, and a rude zonal distribution is observed to be dependent upon the position of the deposit relative to the granite intrusive. In this way, mineralization nearest the granite contact is characteristically composed of auriferous pyrite, chalcopyrite, and quartz. This grades outwardly to mineralization in which galena and silver become important constituents along with lesser amounts of auriferous pyrite. Within the granite, this relation is not as well defined, but the deposits are probably produced through the effects of local, internal mineralizing sources. The Potosi district is probably the best representative of high temperature or hypothermal mineralization, as it contains important occurrences of fluorite and hubnerite. The other veins, in which silver minerals occur, probably represent lower temperature deposits or a much later period of metallization. At the Bismark mine, near the head of South Boulder Creek, the mineralization in veins at or near the granite-gneiss contact consists of chalcopyrite, pyrite, and molybdenite in quartz.

No true contact metamorphic deposits are known within the area. Classification of the ore deposits according to genetic relations conforms reasonably well to the zonal distribution suggested above and permits the following general divisions:

Hypothermal deposits.--The tungsten-fluorite deposits of the Potosi district and the chalcopyrite-molybdenite veins of the Bismark area are apparently high temperature, hydrothermal ore deposits.

Mesothermal deposits.--It is the writer's opinion that most of the deposits of the Pony region are of the mesothermal type, and consequently, a sub-classification into higher and lower temperature mesothermal deposits is attempted. This division is based on distinguishing cupriferous and auriferous pyritic deposits signifying higher temperature deposition from auriferous pyrite deposits associated with galena and believed to represent lower temperature deposition. In the former group, are included the Old Joe, Mammoth, Boss Tweed, Clipper, Atlantic and Pacific, Mountain Cliff, and other mines. In the latter are included the Garnet, Pan American, Strawberry, Oregon, Norwegian Creek deposits, and others.

Epithermal deposits.--Distinctive features characteristic of epithermal deposits are not commonly present in the Pony region unless the silver bearing veins of the Potosi district are possible exceptions. This condition in general suggests that the deposits as observed today represent the more deep-seated roots of veins, the upper portions of which have been removed by erosion.

In line with genetic relations, attention is called to the frequent association of ore deposits with pegmatite dikes. It appears most likely that these dikes represent an earlier phase of magmatic differentiation, preceding the introduction of hydrothermal solutions. The fact that pegmatite dikes often occupy breaks or fissures which now also contain the veins merely indicates the existence of the major structural breaks at the time of the dike injection, and further suggests that post-dike stresses were also relieved along these same pre-existing zones of weakness. Thus post-dike mineralization often both replaces dike minerals and occurs at a distance from any dike. Similarly, it is logical to assume that at points where fissures were permanently sealed by dike intrusions, the later hydrothermal solutions could not enter. This condition could give rise to apparent gradations from true hydrothermal veins to true pegmatite dikes and thereby imply a closer relationship between the two than is actually the fact.

Hydrothermal alteration of wall rock associated with the veins of the Pony region is rarely well developed. The most important exceptions are at the Boss Tweed and the Atlantic-Pacific mines, in which wide altered zones are developed. In both, the country rock is so completely silicified and sericitized as to mask almost completely its original character. Along the Mammoth vein, alteration is also quite advanced.

Surficial alteration and secondary enrichment by meteoric waters are quite general, but differ in intensity from place to place. Probably the most outstanding example of an enriched ore shoot is in the Clipper mine. In the upper workings of the Mammoth mine, near-surface enrichment was noted with respect to both gold and copper. In most of the smaller veins, as at Norwegian Creek, the chief value of the deposits results from the near-surface enrichment of gold content in the oxidized zones. Secondary sulphide zones are not outstanding.

DESCRIPTION OF MINING PROPERTIES

Although all properties of the Pony area are not described an attempt is made to present rather full details of the more important properties characteristic of the several types of deposits present in the area.

Mineral Hill District

Boss Tweed and Clipper.—The Boss Tweed and Clipper mines, operated as a single property, are on separate veins. They are four miles west of Pony, near the head of Pony Creek at elevations of approximately 7,000 feet. Both mines are developed by adit drifts on the veins which lie parallel and 600 feet apart. The lower tunnel on the Clipper vein is connected with the 600-foot level of the Boss Tweed, thus giving underground connections through raises and stopes to the Boss Tweed 700-foot level, which is at the mill elevation.

The Clipper vein strikes N. 60° W. and dips 40° southwest. Adit openings have explored the vein 1,200 feet longitudinally and 500 feet on the dip.

The ore occurs within distinct foot wall and hanging wall fault slips which are from 10 to 40 feet apart. The vein filling or mineralization consisted originally of quartz and auriferous pyrite as a partial replacement of the gneiss between the vein walls. Oxidation has been quite intense ip the Clipper, and this condition has undoubtedly increased the gold content considerably in the near-surface ore shoots. The development on the 600-foot level has not disclosed any commercially important ore bodies. The important production from the upper levels was from several shoots which pitched quite uniformly down dip. Nearly 90 per cent of the milling ore, which averaged about $10 a ton in gold, was obtained from two shoots, one of which extended from the surface almost to the 600-foot level.

The mine is credited with a total production of nearly $2,000,000.

According to reports, the Indian Gold Mining Company took over the Boss Tweed group of eleven claims in 1900 for $600,000. At that time, the property was opened by a surface cut, the 300-foot level adit, and the 600-foot level adit. The 600-foot adit represented 1,000 feet of drifting along the hanging wall, and exposed the vein at a depth of 360 feet below the open cut. The Indian Gold Mining Company undertook an extensive development program which included opening the vein at 100-foot intervals relative to the 300 level. Upon completion of this program, an 800-foot level, four adit levels, and a 500-foot intermediate level were established giving a total of 8,000 feet of drifting on the vein. While this work was being done, a 100 stamp mill and a power plant were installed at Pony, and a tramway connection between the mine and mill was surveyed and equipment secured. Further, 4,400 tons of ore with a gross value of $220,000 were extracted and shipped from the 700 level. For reasons not wholly clear, the Indian Mining and Milling Company relinquished its interest in the property in 1904, and since that time, under various leases to W. W. Morris or his sons and associates, the property has yielded in excess of $200,000 from shipping ores.

The ore-body is a replacement deposit in altered gneiss between two definite fault walls which diverge southeasterly from a width of 100 feet to more than 200 feet. The fault walls trend roughly N. 60° W. and dip 50° to 70° southwest. The mineralization, consisting of quartz and pyrite bearing gold, differs in intensity, and commercial ore occurs in shoots; but the entire mass is mineralized to some extent.

The facts causing the localization of ore shoots are a problem of great economic importance for future operation of the property. In general a system of transverse fissures with low east dips appears to bear some relation to the shoots which also generally rake easterly. Again, richer ore rarely occurs along or within ten to twenty feet of the hanging wall clay. This factor greatly increases the difficulty of exploration. The foot-wall break is not continuous, but appears to consist of a series of enechelon breaks, each unit being offset to the left, causing a divergence from the uniform hanging wall in a southeasterly direction. It is very probable that transverse deformation is greatest at points coinciding with the enechelon gaps and that such breaks represent areas most favorable to ore shoot localization.

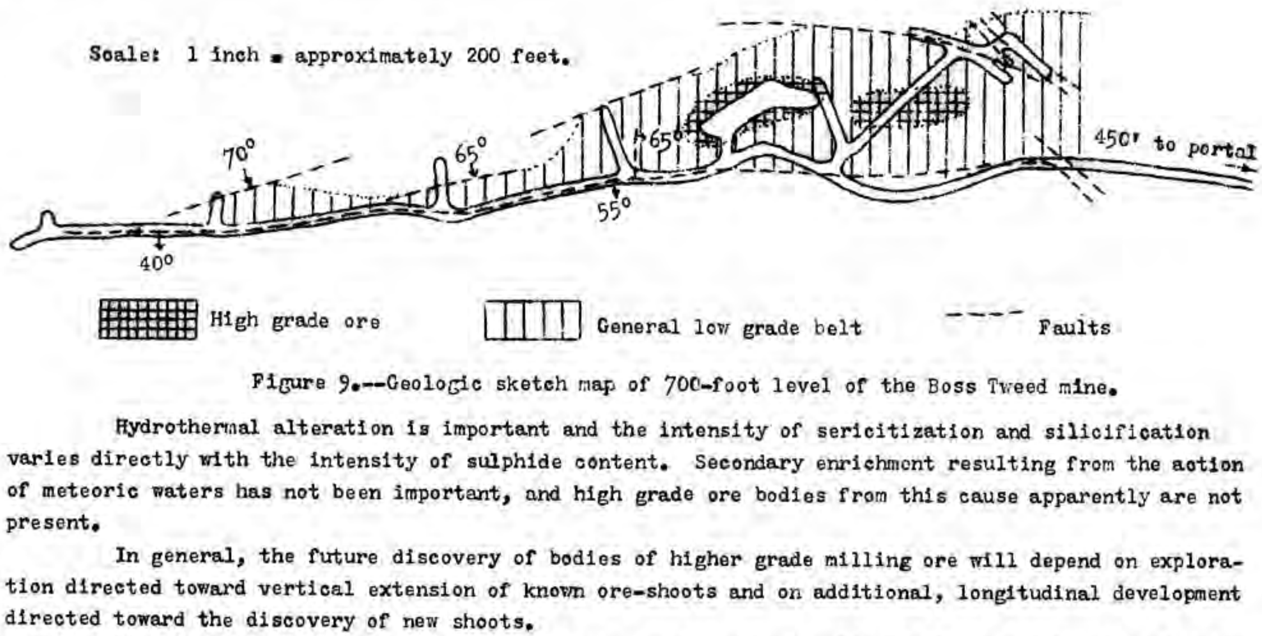


Figure 9.--Geologic sketch map of 700-foot level of the Boss Tweed mine.

Hydrothermal alteration is important and the intensity of sericitization and silicification varies directly with the intensity of sulphide content. Secondary enrichment resulting from the action of meteoric waters has not been important, and high grade ore bodies from this cause apparently are not present.

In general, the future discovery of bodies of higher grade milling ore will depend on exploration directed toward vertical extension of known ore-shoots and on additional, longitudinal development directed toward the discovery of new shoots.

As indicated above, the entire mineral zone contains some gold and offers possibility of being developed into a large low-grade ore-body, which, however, will depend on many favorable factors for its commercial importance or value.

Atlantic and Pacific mine.--The Atlantic and Pacific mine is six miles west of Pony, on the divide between South Boulder Creek and the head of Cataract Creek at an elevation well above 8,000 feet. An aplite (alaskite?) dike, bounded on the north by normal granite and on the south by gneiss, trends in an easterly direction. Fracturing within the dike has opened it to mineralizing solutions, and where the fracturing was most intense, the more important bodies of auriferous pyrite and quartz were developed. Replacement of the wall-rock is also important in the more heavily mineralized zones. (See fig. 10.)

Development includes a lower tunnel which extends along the major faulted zone for a distance greater than 600 feet, short transverse crosscuts, and a series of surface cuts. The strongest showing of ore exposed is in one of the open cuts. This ore body, which assays approximately $10.00 a ton in gold, is apparently 20 to 30 feet wide but has not been sufficiently developed to determine its length. The lower tunnel covers both a vertical projection and the projection of any possible west rake of this shoot, but does not eliminate the possibility of the shoot pitching easterly. It may be of interest to recall that ore shoots in the Clipper, Boss Tweed, Mammoth, and many other mines of the district rake easterly.

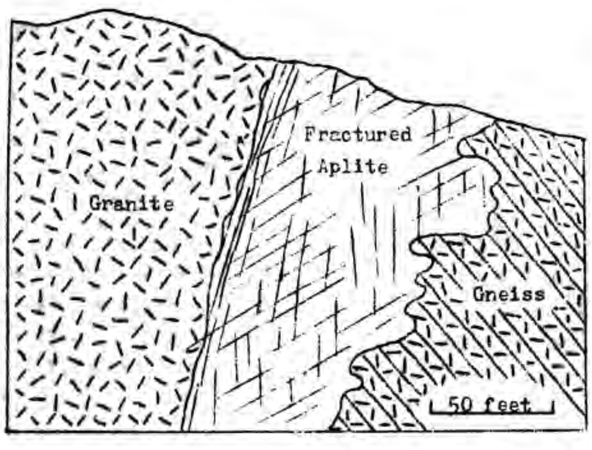


Figure 10.--Sketch of section across Atlantic and Pacific mineral zone. Cross fractures in aplite are filled with auriferous pyrite.

A second strong surface indication was observed on the Atlantic claim approximately 500 feet east of the ore zone described above. A 200-foot adit has been recently driven just west of the exposure, but ore was not found. The negative results may again be due to a tendency toward east raking ore-shoots. A crosscut driven easterly from this adit at a point 100 feet north of the portal would determine this possibility.

Strawberry-Keystone group.--In the Strawberry-Keystone group, about 2 1/2 miles west of Pony, two important veins have been explored. The veins, known as the Strawberry and the Keystone, strike eastward and dip respectively 55° northerly and 50° southerly. The veins, at least where accessible to inspection at this time, exhibit a tendency to split, and ore shoots occur at or near these junctures. The development work now accessible consists only of the lower, or Keystone tunnel and some new work on the Keystone vein several hundred feet west of this development. In the main lower tunnel

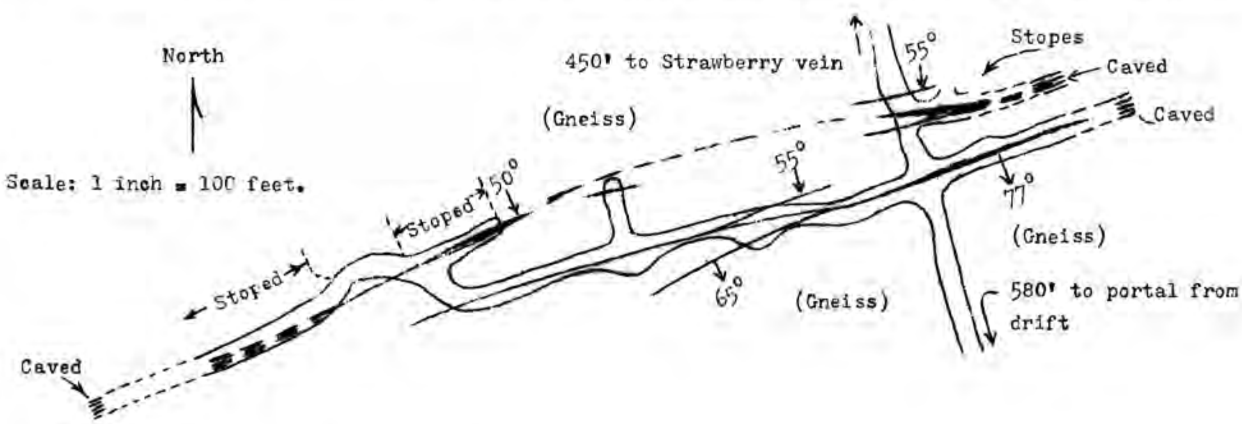


Figure 11.--Geologic sketch of the Keystone vein.

both the Strawberry and Keystone veins are exposed, the Strawberry for 250 feet and the Keystone for approximately 500 feet. On this exposure of the Strawberry vein, no important mineralization is exposed except at one point in the hanging wall of the vein about 100 feet east of the crosscut. Here, over 8 feet of milling ore is exposed. It consists of a heavy dissemination of auriferous sulphide reported to average about $7 a ton in gold. The Keystone vein is opened by a lateral in the hanging wall of the vein. Crosscuts to the footwall indicate that important mineral zones are formed in the footwall portion of the structure. Present development has been limited to two places only, and some stoping has been done at both. (See fig. 11.)

A recent exposure on the Keystone vein several hundred feet west of former work, although not high grade, is encouraging, because it indicates that fairly strong mineralization has been tested at only one point along the vein.

The gross production from the group is reported to be in excess of $150,000, of which 75 per cent consisted of milling ore.

Garnet mine.--The Garnet mine, on Cataract Creek, 2 miles southwest of Pony, differs from those just described in that it occurs wholly within the granite. The main tunnel is driven N. 30° W. approximately 1,300 feet. At least four veins, striking N. 60° E., were cut and several hundred feet of drifting, mostly northeasterly, completed on each. The two most important veins of this group are known as the Galena and the '149' veins.

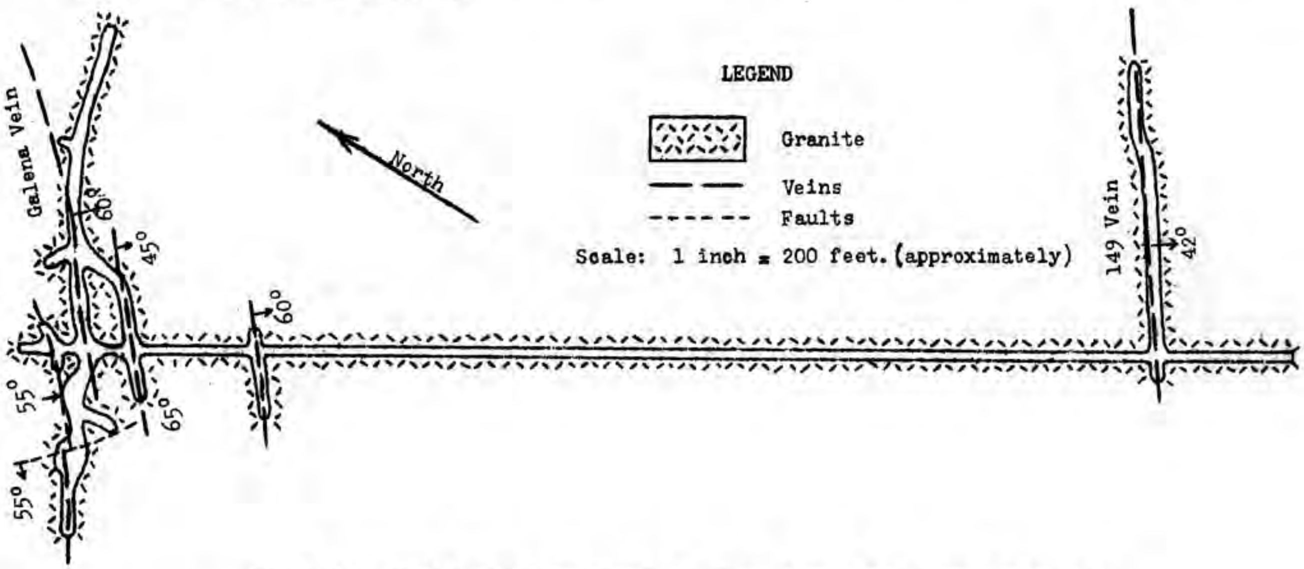


Figure 12.--Sketch of main tunnel workings, Garnet mine, Pony district.

The mineralization consists of quartz, galena, and auriferous pyrite. Most of the ore milled was oxidized and only in the lowest development on the 149 vein is unaltered sulphide material exposed. In these workings, the vein is narrow, averaging about one foot in width, and the shoots are short, but the rich material is sufficiently high grade to permit direct shipment.

Production records indicate that 175,000 tons of $4.00 ore was milled during a period extending from 1898 to 1905. Most of this was derived from the Galena vein.

South Boulder District

Mammoth mine.--The Mammoth mine is on the east slope of South Boulder Creek valley. The mine is developed by five adits which explore the vein for a lineal distance of 3,000 feet and a maximum vertical distance of nearly 1,000 feet.

The mine has been known and operated for many years, and it is believed that the early mining of near-surface ore-shoots yielded a fair profit. Since the advent of flotation, the mine has been a more or less continuous producer of concentrate and the gross value of all ore produced is estimated to approach $2,000,000.

The geology of the Mammoth mine is relatively simple, all operations being confined to one major fissure vein trending easterly and dipping 60° southerly. The host rock is gneiss and schist of the Pony series. The vein cuts across the banding of the gneiss. Numerous pegmatite dikes occur in close proximity to the Mammoth vein and in places these are cut by the vein itself.

The mineralization in the Mammoth area appears to be a westward extension of the Mineral Hill zone in which the Boss Tweed, Clipper, and other important properties occur. The commercial mineralization occurs in shoots of irregular outline in two general mineral zones. These two zones, designated as the West shoot and the East shoot respectively, are readily recognized on the accompanying longitudinal projection. (See pl. 5, B.) The West shoot pitches steeply but the East shoot rakes flatly to the east.

The occurrence of ore lenses within these shoots is apparently determined by variable structural factors. Fissure intersections and certain hanging wall to foot wall relations within the main fissure are the most important controls. (See figs. 13 and 14.)

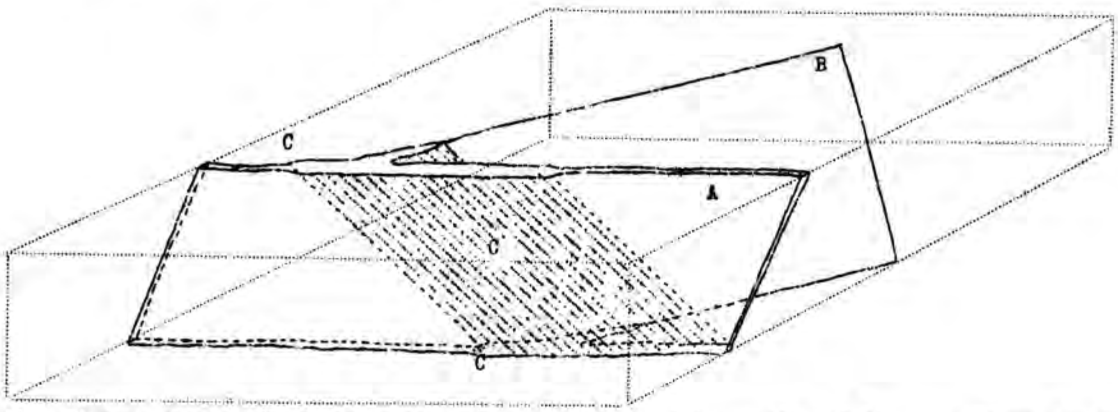


Figure 13.--Diagram showing the localization of ore-shoots by intersection of fissures, Mammoth mine. Vein A, striking east and dipping south, is intersected by vein B, striking northeast and dipping southeast, the resulting ore-shoot C being formed along the line of intersection C - C.

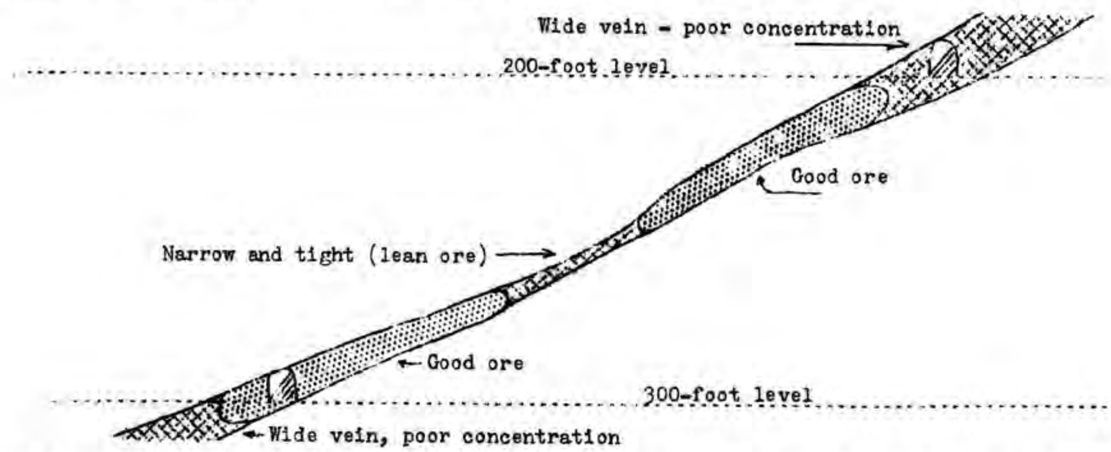


Figure 14.--A sketch of the cross-section of a vein to show the relation of the character of the walls to the localization of ore-shoots, Mammoth mine.

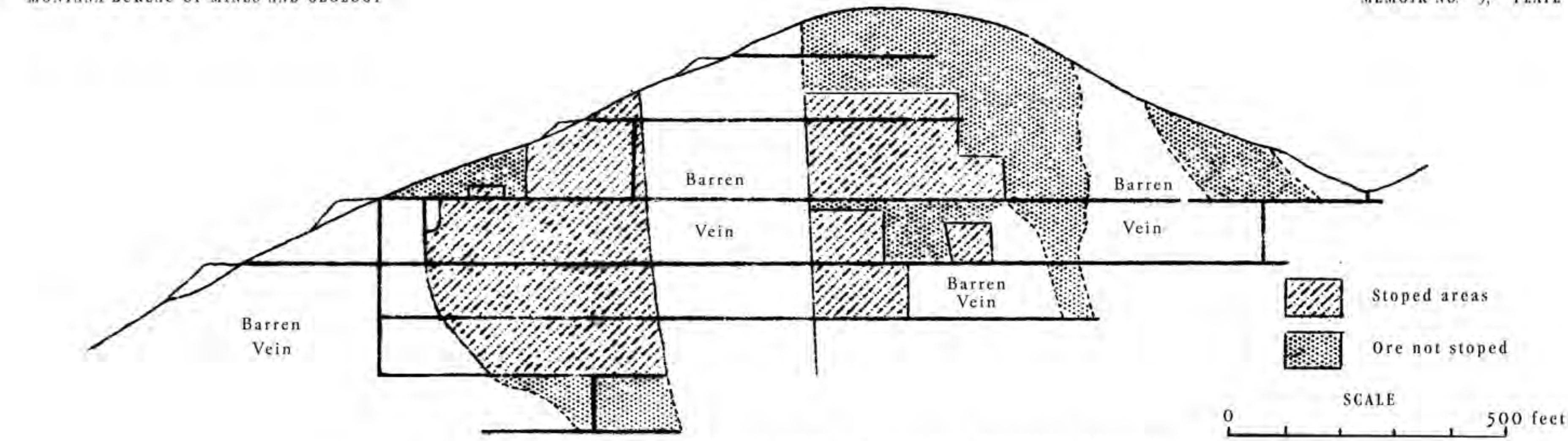
The size of the commercial ore lenses varies greatly. The largest single lens developed is over 300 feet in length and height. The tendency of these shoots to terminate abruptly makes development work precarious and expensive, but if the true facts are recognized, a systematic development program conducted within the general ore zone limits and projections, should result in the discovery of more ore.

The mineralization consists of auriferous pyrite and quartz with a subordinate amount of chalcopyrite. The ores carry silver in a ratio of about two ounces to one of gold. The copper content is about one per cent to every ounce of gold.

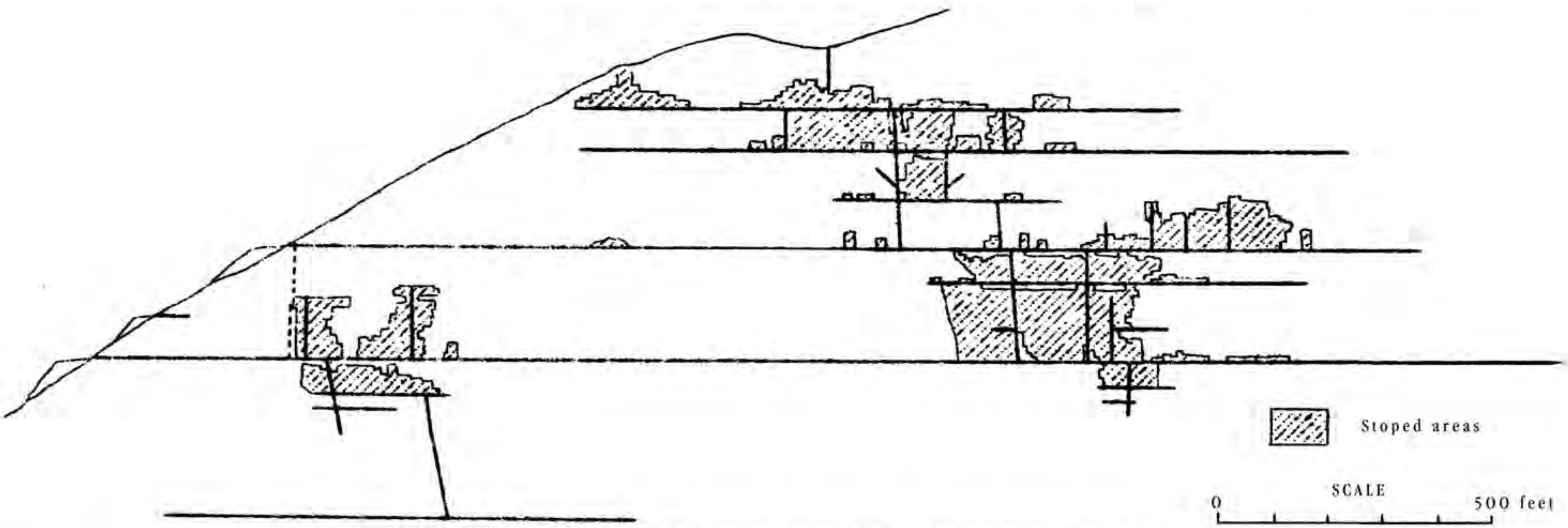
Secondary enrichment processes have been active in locallizing rich bodies of copper and gold in the upper, near-surface zone, but are probably of little importance in the deeper workings which may be said to exhibit characteristics of true primary ore.

The present development does not adequately determine the probable depth of ore-shoots. The irregularities described above indicate that unsuccessful development does not definitely disprove ore possibilities at still greater depth, and consequently, a full and systematic development of the downward projection of the East shoot is likely to add to the ore reserves. The West shoot was never as strong or as valuable, and additional exploration therein should be done with caution.

Several other veins, parallel to the Mammoth, are too incompletely developed to permit thorough observations. Some production has been reported from these, but in general, they do not represent structures of mineralization comparable to those in the Mammoth mine.



A. SECTION ALONG VEIN, EASTON MINE, VIRGINIA CITY DISTRICT, MONTANA.



B. SECTION ALONG VEIN SHOWING STOPES, MAMMOTH MINE, PONY DISTRICT, MONTANA.

Bismark mine.--The Bismark mine is about three miles south of the Mammoth near the forks of South Boulder Creek. In this property, now idle, several fissure veins near a granite-gneiss contact have been partially developed. The mineralization consists of pyrite, chalcopyrite, and molybdenite with quartz in small, narrow ore shoots. The veins are not strong or continuous, but are numerous.

In the vicinity of the Bismark mine both the gneiss and granite near their contact are generally weakly fissured and mineralized. Some development of local zones of more intense fissuring has suggested a large tonnage of low-grade ore, but development completed to date has not exposed any of this material of commercial importance.

Renova District

Mayflower mine.--The Mayflower mine, in the Renova or Cedar Hollow district nine miles north of Mammoth, represents a quite different type of high-grade gold occurrence as compared to others of the Tobacco Root area. Under the Clark management, almost entirely between 1896 and 1901 inclusive, the mine yielded approximately $1,250,000 from high-grade shipping ore averaging $150.00 a ton in gold. This ore was stoped entirely above the water table encountered on the 300-foot level. Below this level, the production is unknown, but the area of stopes is nearly equal to that above the water table. The main lower stope extends from the 300-foot level to the 700-foot level. The West Mayflower adjacent to the Mayflower, probably produced about $50,000 in gold from much lower grade material.

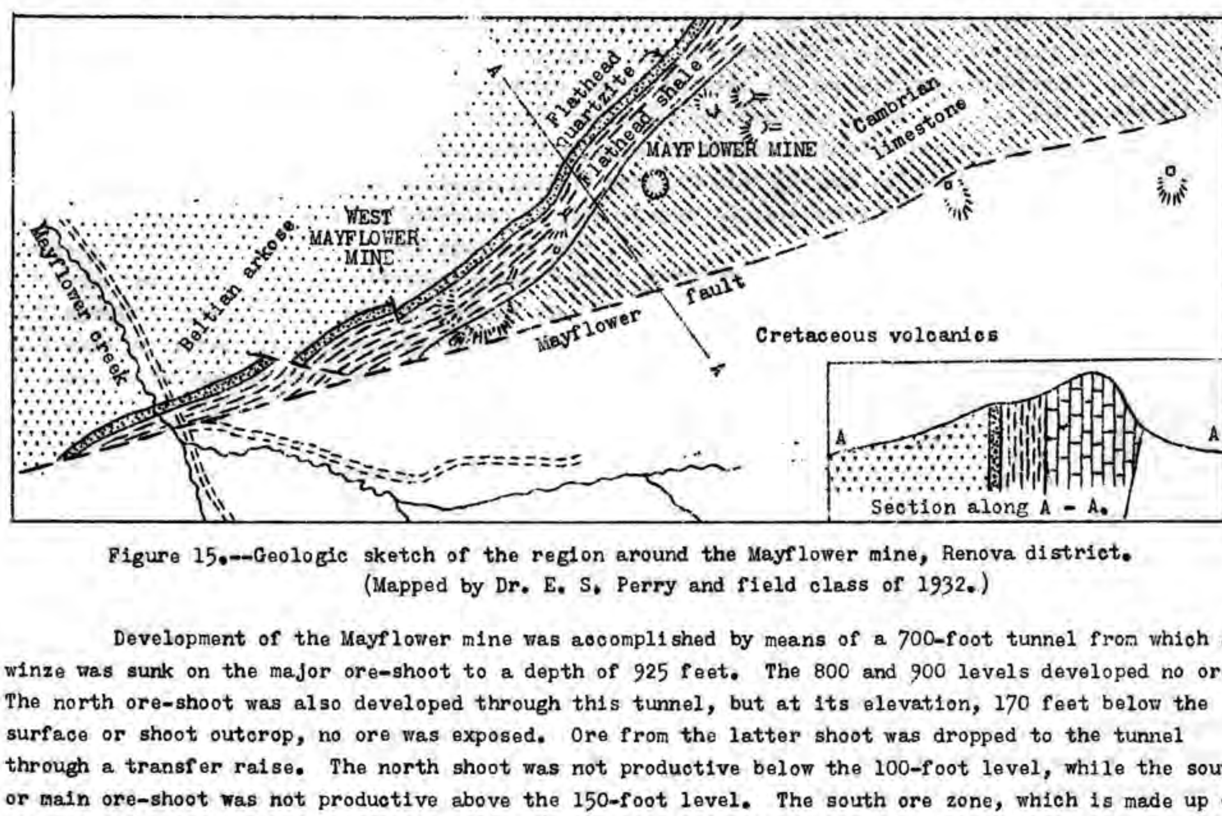


Figure 15.--Geologic sketch of the region around the Mayflower mine, Renova district. (Mapped by Dr. E. S. Perry and field class of 1932.)

Development of the Mayflower mine was accomplished by means of a 700-foot tunnel from which a winze was sunk on the major ore-shoot to a depth of 925 feet. The 800 and 900 levels developed no ore. The north ore-shoot was also developed through this tunnel, but at its elevation, 170 feet below the surface or shoot outcrop, no ore was exposed. Ore from the latter shoot was dropped to the tunnel through a transfer raise. The north shoot was not productive below the 100-foot level, while the south or main ore-shoot was not productive above the 150-foot level. The south ore zone, which is made up of two major and one minor ore-shoot, averaged 60 feet in length, 5 feet in width, and extended nearly 700 feet vertically. The north shoot, shaped as an inverted triangle with legs 120 feet long, was stoped for an average width of five feet.

The West Mayflower mine was developed by tunnels and winzes but only one small commercial ore-shoot was discovered.

The ore-bodies of the Mayflower group lie on the northwest side of a strong fault, trending N. 50° E. and dipping nearly vertical. The fault cuts intercalated limestone and shale beds of Cambrian age. The principal ore-shoots are associated with the limestone members.

The character of the hypogene mineralization is very difficult to determine because of the inaccessibility of the workings. The material mined above the 300-foot level was entirely oxidized and enriched by surficial agencies. Commercial sulphide or telluride ores continued below the 300 level almost to the 800 level. Tellurium was noted in the ore shipped, and it is believed that tellurides were present in the primary mineralization.

Considerable exploration on the Mayflower vein to find other ore-bodies has not been successful.

Other mines in the Renova district.--For many years there has been no important mining activity in the several properties near the Mayflower mine in the Renova district. Most of these properties were visited and described by Winchell (U. S. G. S. Bull. 574), and as there has been no significant new development since that time, no additional description is included in this report. It is worthy of mention, however, that each of these deposits which include the Surprise, Mary Ingaber, Colorado, Blue Bird, and Gold Hill mines is in Upper Beltian arkosic sandstone. Each occurs in a strong fissure zone cutting these rocks and constitute the only known ore deposits related to Beltian rocks in the area.

Potosi District

The Potosi district is several miles southwest of Pony and is entirely within the granite belt. Aplite (alaskite) segregations in the granite are extensive in the Potosi section, and in these occur most of the important veins containing hubnerite and silver.

The veins trend easterly and dip steeply to the south. The silver bearing veins occur parallel to and north of the tungsten belt, and probably represent a later period of mineralization.

The tungsten mineral hubnerite occurs as seams in wide, massive, white quartz veins or dikes of pegmatitic character. Along the hanging wall fluorite filling may be noted. (See fig. 16.) The hubnerite occurrences, although of great extent, vary greatly in intensity and only lens-like zones constitute possible ore resources, but it is apparent that under favorable market conditions, the veins would warrant further exploration. Although the silver veins were moderately productive many years ago, no work is being done on them at present.

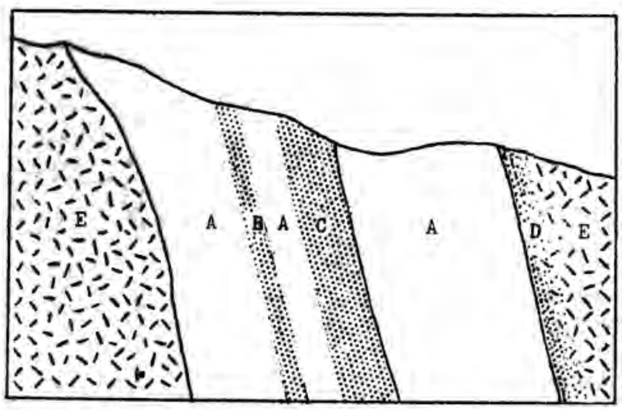


Figure 16.--Sketch of typical tungsten deposit in Potosi district. A, Barren quartz; B, smoky bands --microscopic segregations of hubnerite; C, 24" to 30" band containing numerous bands of 1/4" to 1/2" crystals of hubnerite; D, altered band--12" wide contains much fluorite; E, alaskite.

Norwegian District

The Norwegian district, on Norwegian Creek a few miles southeast of Pony, is entirely within the granite. A complex system of veins is developed in which those striking N. 40° E. and dipping 60° south appear to be the most important when intersected or joined by those striking N. 10° E. A third set of veins striking N. 10° to 20° W. are less productive. Oxidized and enriched gold ore was extracted chiefly from shoots formed at vein intersections, as on the Norwegian, Amy Louise, Red Chief, and other properties. Commercial ore was confined to the near-surface zone and at such points high-grade shipping ore was most frequently obtained. The veins are narrow, and consequently no important developments at depth are anticipated, but the discovery of new oxidized ore-shoots is very probable through additional longitudinal exploration of the known veins. Further general prospecting may result in the discovery of new veins.

TWIN BRIDGES REGION

In this report the Twin Bridges or Tidal Wave district includes the area drained by the westward flowing streams between Wet Georgia Gulch to the south and Belle Canyon to the north.

PRODUCTION

Available production records of the Twin Bridges district date back only to 1904. Earlier annual production for the district probably equaled or even exceeded the average annual production since 1904, but no definite information on this can be secured. In the following table, statistics from 1904 to 1912 inclusive were compiled from United States Geological Survey Bulletin 574; and from 1913 to 1930, from 'Mineral Resources of the United States'. Part of the production from the Twin Bridges (Tidal Wave) district has been reported as coming from the Silver Star district, and consequently some of the figures in the following table may be somewhat low.

Mine production of gold, silver, copper, lead, and zinc, Twin Bridges district, Montana, 1904 to 1930

Year	Mines Reported	Ore	Gold	Silver	Copper	Lead	Zinc	Total Value
		short tons		fine ounces	pounds	pounds	pounds	
1904	---	21	$ 820	140	------	8,000	------	$ 1,060
1905	---	114	15,564	17,742	309	59,485	------	29,126
1906	---	178	4,844	9,775	3,766	68,066	------	12,649
1907	---	184	7,652	2,026	------	55,636	------	11,938
1908	13	1,454	11,935	6,866	3,935	144,689	------	22,171
1909	19	468	15,596	10,056	882	155,942	------	27,695
1910	8	677	15,423	7,459	2,307	118,551	------	24,960
1911	23	400	12,335[b]	6,415	2,205	146,801	------	22,616
1912	23	242	7,840	7,600	3,673	42,573	------	11,916
1913	5	334	11,636	2,355	8,245	20,910	------	15,257
1914	12	1,373	24,278	5,653	24,453	65,402	------	33,207
1915	23	1,100	(a)	(a)	------	(a)	------	------
1916	21	1,852	92,436	10,636	52,862	240,357	------	129,022
1917	25	6,973	50,546	10,026	14,633	190,781	------	79,209
1918	11	2,101	18,937	7,959	7,681	190,789	11,114	43,350
1919	10	293	9,481	5,521	4,351	98,292	------	21,682
1920	7	337	5,083	5,245	373	110,085	------	19,676
1921	11	137	4,439	1,302	1,712	35,583	------	7,563
1922	10	175	3,931	2,653	5,063	7,982	------	7,707
1923	11	261	6,074[b]	2,314	986	92,612	------	14,620
1924	14	339	2,619	2,320	1,303	84,530	------	11,106
1925	12	237	1,871	3,022	1,574	141,303	10,773	17,305
1926	12	242	6,436	2,087	40	107,612	------	16,353
1927	10	186	16,642	2,659	------	34,078	------	20,297
1928	19	117	8,712	769	519	22,257	------	10,528
1929	4	28	1,021	------	257	------	------	1,125
1930	10	143	5,067	790	840	21,414	------	6,551
Totals		29,966	$361,218	133,390	141,969	2,263,730	21,887	$618,689

(a) Quantity or value of production not recorded, (b) Includes production from placers.

GEOLOGY

The geology of the Twin Bridges district is more complex than that of any other region of the Tobacco Root area. Although pre-Beltian gneiss and schist occupy the major portion of the area, outcrops of Paleozoic quartzites, shales, and limestones are extensive. The relations of the two series are further complicated by strong faulting, which causes complex repetition of the two series at several places. The relation of igneous rocks is also complex. Igneous rocks are exposed in several areas of granite and porphyritic rocks, and as sills. They exert important influences upon the associated or resultant ore-bodies as will be described below. The areal distribution of all these rocks has been outlined in Part I, of this report, and are shown on the geologic map. (See pl. 1.)

The ore-deposits of the Twin Bridges area are of several types which may result from varied genetic conditions. Typical fissure veins containing gold, silver, lead, copper, and zinc, which occur either within the monzonitic masses or in the adjacent gneissic areas, are best developed in the upper Bear Gulch region. A somewhat related type of deposit is the lead-silver and to a less extent, copper-gold deposits in Paleozoic limestone near granite contacts. Another type in which the granitic relation is not apparent includes lead, zinc, copper, and silver ore-bodies in limestone at points a short distance from igneous sills. This latter type is important in Goodrich, Dry Georgia and Wet Georgia gulches. Winchell believes that the deposits related to sills are earlier than those related to the granite intrusives, and in general no definite information disproving this opinion has been observed except possibly that the hypersthene gabbro exposed in Upper North Meadow Creek can be definitely traced to the granite.

Structurally, the deposits of the district differ according to the above types. The fissure veins related to monzonite suggest local stresses and consequently are not correlative between different areas. The contact deposits are also local, and occur mainly as replacements in limestone along fissures both parallel and transverse to the contact planes. Deposits related to sills usually occur in bedding planes. As the sills are uniform and persistent, some of these deposits are traceable for many hundreds of feet.

The mineral deposits of the Twin Bridges district generally contain important amounts of lead and silver. Auriferous pyrite is the principal constituent in some deposits, as in the Bielenberg and Higgins mine, and in the Corncracker, and is present in lesser amounts in the primary ones throughout the district.

Hypogene alteration has not been important in any of the deposits of the district except possibly at the Corncracker mine. At this mine topographical and structural relations suggest intense action of surficial waters. Surficial enrichment is not exceptionally important in the district although the rich near-surface gold ore-bodies of the Pete and Joe vein (Bielenberg and Higgins mine), the Eleanora vein (Crystal Lake), the Corncracker, and others resulted from concentration by this process. Enrichment in the predominantly lead bearing deposits has increased the gold-silver content of the near-surface zones. Lead is not enriched appreciably by the action of surficial processes.

DESCRIPTION OF MINING PROPERTIES

Upper Bear Gulch Properties

Bielenberg and Higgins mine.—The Bielenberg and Higgins mine (now operated by the Inspiration Gold Mining Company) is at the head of Bear Gulch on the west slope of A. P. A. Mountain. The main workings are at elevations between 8,000 and 9,000 feet. The principal developments are within a small monzonite plug penetrating gneiss and schist. A number of fissure veins have been exposed in the various workings, but the Pete and Joe, and the Paige, both striking N. 30° E. and dipping 50° to 60° westerly, and the Incline vein striking nearly north and also dipping westerly, but at a low angle, have been the important producers. Mining widths average from 3 to 5 feet. An east-west vein, exposed near the portal of the main B and H tunnel also yielded some ore. The winze on this vein is now inaccessible. This vein appears to conform to a major plane of weakness in the area, and a multitude of small stringers were cut in the main crosscut referred to above. It appears likely that certain portions of this intensely sheared and mineralized zone may constitute a stringer lode of commercial importance, provided development can be directed toward successfully blocking out bodies of sufficiently high grade material to permit mining by non-selective methods.

The mine is developed by a main tunnel (B and H) at the head of the main branch of Bear Gulch. The upper tunnels, on the opposite side of a ridge separating Bear Gulch from a southeast tributary, are commonly referred to as the Pete and Joe workings, although both are connected by intermediate development. Below the main B and H tunnel, two levels at 100-foot intervals have been established from an incline shaft sunk on the Pete and Joe vein. A tunnel approximately 500 feet below the B and H tunnel, at mill elevation, has been extended to a total of 1,200 feet toward the downward projection of the B and H shaft. An equal additional advance is required before the Pete and Joe vein projection is reached.

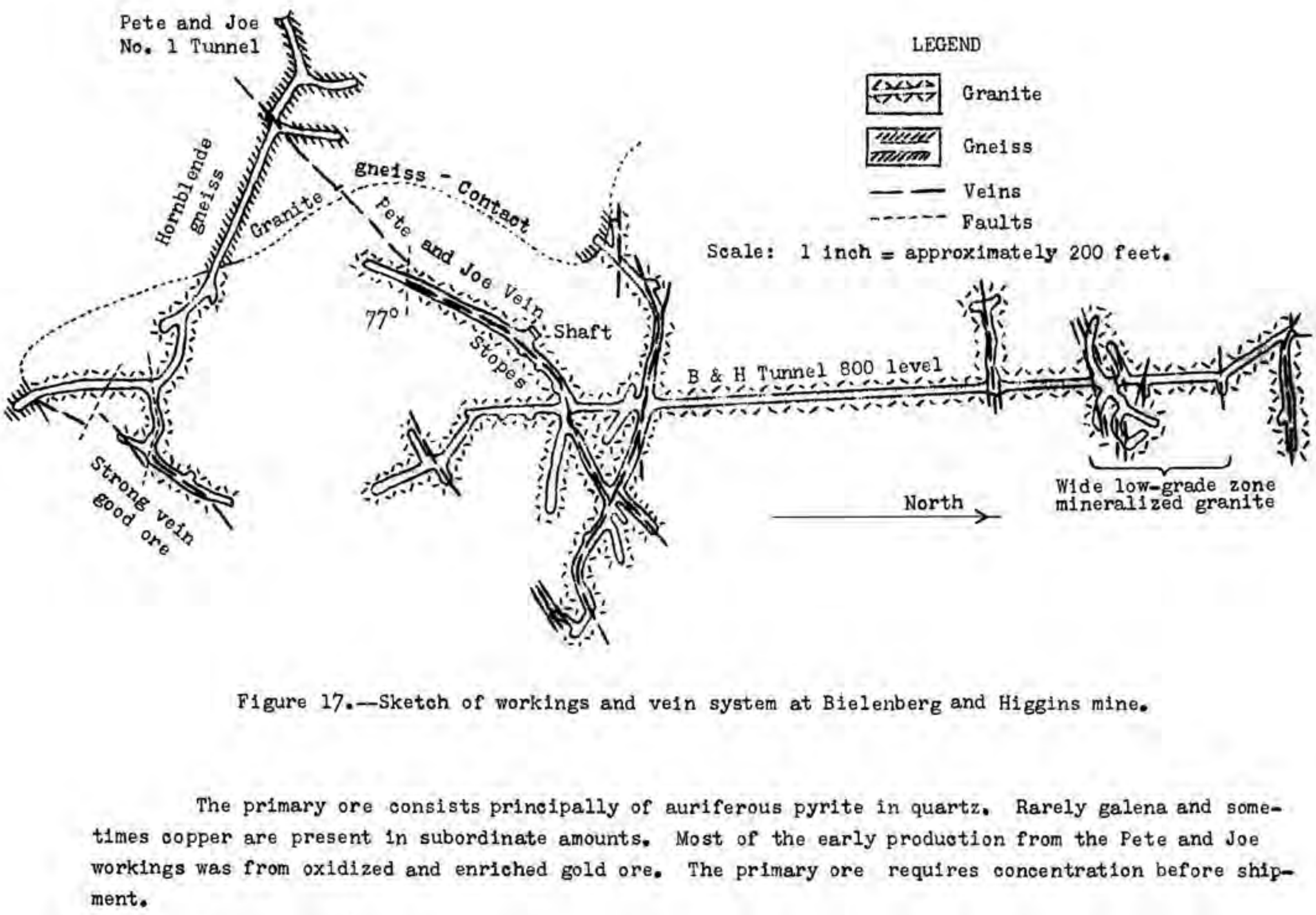


Figure 17.—Sketch of workings and vein system at Bielenberg and Higgins mine.

The primary ore consists principally of auriferous pyrite in quartz. Rarely galena and sometimes copper are present in subordinate amounts. Most of the early production from the Pete and Joe workings was from oxidized and enriched gold ore. The primary ore requires concentration before shipment.

In general, the veins exposed in the B and H workings are not extensively prospected lengthwise, and as the ore occurs in shoots separated by barren gaps conditions are favorable for successful prospecting.

Other Upper Bear Gulch properties.—The geological conditions in the Upper Bear Gulch area are indicative of generally favorable prospect possibilities in that vicinity. The granitic cupola, in penetrating the pre-Beltian rocks, has certainly effected structural deformation which would result in the development of possible mineral solution channel ways. Furthermore, it has been demonstrated in B and H workings that quite certainly a mineralizing source exists within the granite core. These generalizations are further supported by the widespread presence of rich surface float and the numerous rich showings in shallow surface workings. The type of ore deposit most likely to be discovered is one consisting of small, narrow veins with strongly enriched surface zones. One recent discovery by Mr. A. Pollinger near the head of Dry Boulder Creek appears to represent a vein several feet wide composed of auriferous pyrite and galena in quartz. The longitudinal extent, however, has not been successfully demonstrated, partly because of the steep slope on which the vein crops out, and partly because of fault complications. On shipment of sorted ore from these exposures yielded well over $100.00 a ton in gold.

The Smelter Mountain group of claims is situated about a mile below the B and H mine. Here, a porphyritic sill penetrates Paleozoic sediments and is directly overlain by a limestone member. Lead and zinc ores have been developed in both the porphyry and the overlying limestones.

Little Bear Creek

Little Bear Creek is a north flowing tributary entering Bear Gulch about three miles above its mouth. A group of properties known as the Giant, Copper King, Little Bear, and Grouse are along the west slope of Little Bear Creek valley. Deposits on these claims contain lead and silver mineralization in limestone underlying a porphyry sill, except on the Giant, where jasper ore containing fine gold is present. All these ore bodies, as is characteristic of limestone deposits, are lens-like and irregular.

Dry Gulch

At the mouth of Dry Gulch, which lies between Bear Gulch and Goodrich Gulch, a wedge-shaped block or segment of pre-Cambrian gneiss has been thrust upward, along two faults, into Paleozoic sediments. This relation suggests the probability of a granitic intrusion centering beneath the segment of gneiss. Within the gneissic segment, two parallel veins striking N. 10° W. and dipping 70° to 80° E. have been intermittently prospected for a longitudinal distance of nearly 6,000 feet. Although the development has not exceeded 150 feet in depth, there are several narrow exposures of auriferous pyrite and galena.

As is common throughout the Tobacco Root Range, enriched deposits have yielded some shipping ore, but the objective of present operations is to prove the existence of a resource of milling ore. Although the mining widths may be narrow, the large unprospected lineal extent of the vein lends some promise to the venture.

At the south extremity of the above veins, a vein striking easterly has been opened locally and some shipping ore mined. In the nearby Paleozoic limestones, some prospecting is being done on a rich silver lead.

Goodrich Gulch

The Crystal Lake Mining Company, controls a number of claims in Goodrich Gulch, among which the Elenora, Minnie, Montreal, and Sunbeam are the best developed. The estimated production of oxidized shipping ores prior to 1920 is placed at approximately $200,000. More recently, milling ores have been mined and treated, but the complete production record is not available.

Two important ore-shoots, the Elenora and the Sunbeam have been explored in the extensive workings. Both trend irregularly in a northerly direction and dip 15° to 30° westerly. The Elenora shoot ranges from 100 feet to 170 feet in length, has a dip length of over 500 feet, and widths between one and two feet. A normal fault striking northeast and dipping 50° to 60° E. separates the two shoots and introduces a complex relation between them. As the fault would effect a left-hand displacement, the two ore-shoots above described are probably related to two distinctly separate vein structures. This would imply that the faulted upper segment of the Elenora ore-shoot could be recovered by a southeasterly trending lower tunnel cutting the northeast portion of the Elenora claim. Such development work was recently undertaken and a vein cut at a position indicating the downward displacement on the fault to be approximately 250 feet. Subsequent development on the recovered vein encountered an extremely complex northwest series of normal faults which greatly increased the difficulty of exploration. Although some vein segments were discovered, the complex development work required made additional exploration unattractive.

The mineralization of the two shoots is quite different, and in part, this may be explained by a difference in geological association. The ores in both shoots occur as a filling in fissures in gneiss; but in the Sunbeam, the fissure bears a bedding plane relationship and in general borders or underlies a basic sill. The mineralization in this shoot consists of auriferous pyrite and fine (steel) and coarsely crystalline galena. Coarse galena has been the most important gold carrier.

The primary ore of the Elenora shoot was auriferous pyrite but has been completely oxidized and probably enriched in gold content.

The future resources of the mine lie principally in the indicated lead-gold reserves in the narrow Sunbeam ore-shoot. The ores require milling and may advisably be held until lead prices increase.

The discovery of additional ore in the upper fault segment of the Elenora shoot is possible, and the ore may even be expected to improve as the development approaches the upper oxidized zones; but this is offset by the serious fault complications known to be present in this area.

Dry Georgia and Wet Georgia Gulches

The properties in the Dry and Wet Georgia gulches include the Sunflower, High Ridge, Empire State, Alfreda, Deutschland, Corncracker, and others. The geology of all of these is quite similar, the country-rock being gneiss overlain by Cambrian quartzite, shale, and limestone. In general, the veins are associated with aplite and andesite dikes and sills. Two distinct types of mineralization are indicated: one, resulting in oxidized or enriched gold ore associated with auriferous pyrite, and the other resulting chiefly in silver and lead minerals with small amounts of gold.

The Sunflower vein is developed by two tunnels, the lower one of which exposes a vein with a general northeasterly strike. A strong northeast fault displaces the vein, and the segment developed probably represents the down-thrown block. The vein is narrow, averaging 18 inches to 2 feet in width, and contains argentiferous galena, some sphalerite, and a little gold.

In the High Ridge tunnel, two veins are exposed, the first being nearly flat and averaging 6 to 12 inches in width, the other striking N. 35° E., dipping 65° SE, and ranging from 1 to 6 inches in width. Shipping ore containing chiefly lead, silver, and gold has been gouged from points where the vein exceeds 6 inches in width.

The Empire State vein, developed by two tunnels, is a flat fissure vein in gneiss. It ranges in width from a few inches to two feet. Ore shipments by lessees contained gold, silver, lead, and some zinc.

The Alfreda vein, developed by one adit, strikes N. 53° W., and dips 45° north. The vein, where developed, attains a maximum width of 4 feet and consists of mineralized gneiss carrying manganese, and possibly some gold and silver.

The Deutchland vein strikes N. 15° E. and dips 76° east. It has been developed by cuts, tunnels, and shafts for a total lineal distance of approximately 1,000 feet. One ore-shoot on the Deutchland claim, 100 feet long and 3 feet wide, was mined through an inclined shaft. The ore consists of quartz with bands of galena, a very small amount of pyrite, and sphalerite. All the higher grade shipping ore was found above the 50-foot level although some milling ore is reported in the lower levels.

Shipments from the Deutchland contained 40 to 50 per cent lead, 2 to 4 per cent zinc, 1.8 ounces silver, but no gold.

No ore-shoots were developed by 35 feet of drifting on the vein in the Jersey claim.

A second vein, parallel to and 200 feet west of the Deutchland has been inadequately prospected by cuts, but no commercial ore has been found.

The Cornoracker vein, developed by two adits, is in a strong fissured zone in gneiss. The zone strikes N. 30 E. and dips 70 E. The mineralized zone consists of bands of auriferous pyrite several inches in width within the major fissure zones. Three fairly definite sulphide bands appear to be present and the stoping is directed towards extracting the heavy sulphides for direct shipment. All the commercial ore has been derived from not more than 300 feet of vein, and a gross production of approximately $30,000 is reported.

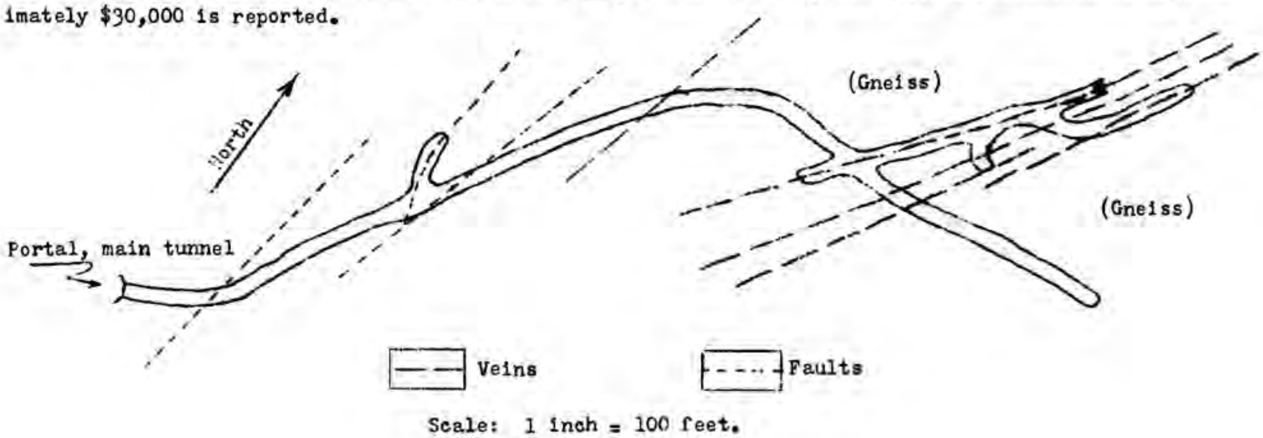


Figure 18.--Geologic sketch of the Cornoracker vein; three or more lenses in a wide altered zone.

The future of this property lies chiefly in the possibility of the discovery of additional oreshoots by extending longitudinal development. The possibilities in depth are indeterminate because of the present limited development. The sulphides disclosed are of a sooty, secondary character. In general, since the fissure structure is very strong and the associated alteration is intense, further exploration of the vein appears desirable.

In the Buckeye tunnel the mineralized material disclosed differs from the others above described in that the manganese content is quite high. The veins occur in Paleozoic limestone in close proximity to parallel granite and porphyry dikes. Very little longitudinal development has been completed on the manganiferous vein, and such development does not seem to be warranted under present market conditions.

Belle Canyon

Strawn mine.--The Strawn mine is in Belle Canyon several miles northeast of Twin Bridges. However, a brief description is presented with the Twin Bridges properties. The Barnes-King Mining Company is said to have mined ore with a reported value exceeding $50,000. Later work by the Jodie Mining and Milling Company succeeded in developing a limited amount of milling ore and some shipping ore, averaging above $30 a ton in gold.

The major vein, which strikes N. 35° E. and dips 35° to 50° westerly, conforms to the bedding planes of Paleozoic limestone, its host. An altered, basic dike, in places occurring as a sill, irregularly follows the vein. (See fig. 19.)

The ore, as disclosed in three adits and connecting stopes and raises, consists of a quartz-filled limestone breccia. Coarse free gold is the chief mineral present. Enrichment may have been an important factor in producing the near-surface shoot mined by the Barnes-King Mining Company. Where better gold content is noted, the vein is several feet wide, but the shoots are irregular, Recent attempts to open the vein below the upper workings and at the same time add to the longitudinal development have not been successful in disclosing commercial ore, but some mineralized material with low silver content was observed.

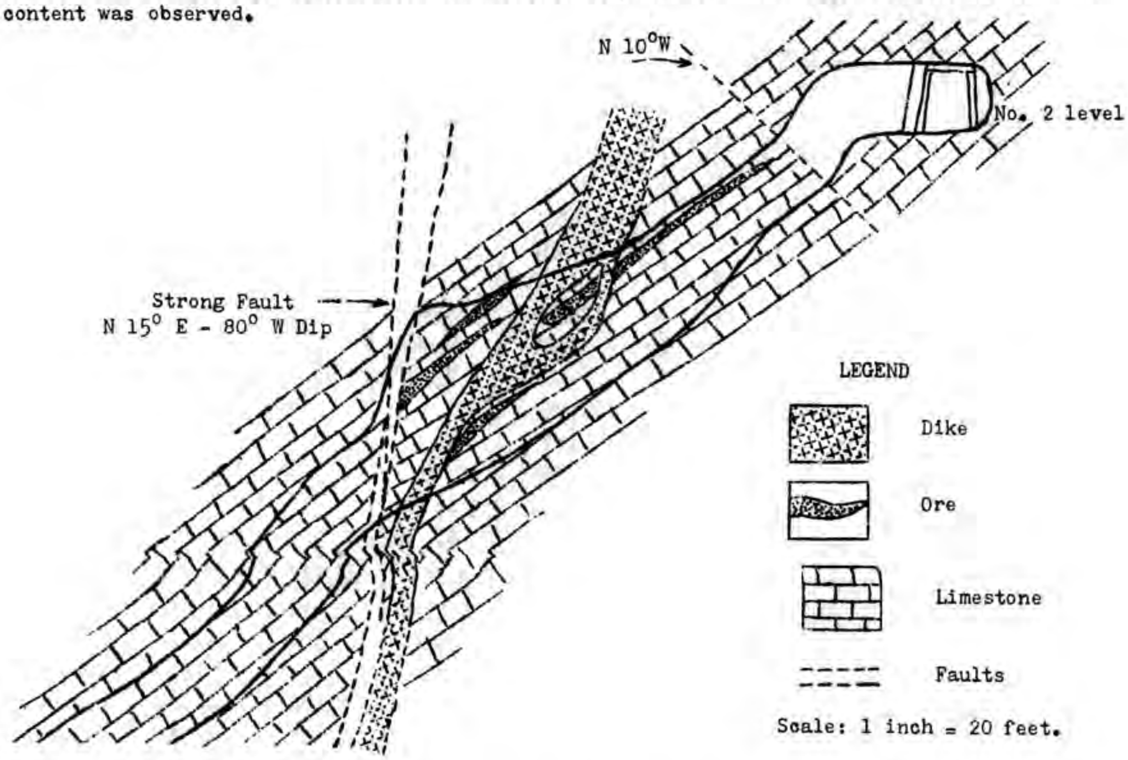


Figure 19.--Section of a portion of the raise between No. 3 and No. 2 levels, Strawn mine; showing relation of basic dike to ore deposit.

S H E R I D A N   R E G I O N

The Sheridan region as considered in this report, includes all mining properties on the west slope of the Tobacco Root range from Wisconsin Creek south to California and Bivins gulches inclusive. This includes several unorganized districts such as Wisconsin, Indian, Brandon (near the mouth of Mill Creek); Mill Creek, Quartz Hill, the ridge between Mill and Indian creeks, Ramshorn, and Bivin districts.

HISTORY AND PRODUCTION

Early development in the Sheridan region closely followed the discovery of gold in Alder Gulch in 1863. The important earlier operations were on the Noble group and at Leiterville. In 1865, the Branham ten-stamp mill was erected. In recent years, the most important development work has been done on the Lake Shore, Red Pine, Fairview, Smuggler, and Betsy Baker properties.

Production records prior to 1905 are not available although the Noble, Leiter, Tamarack, and other properties are known to have been heavy producers before statistics were recorded by the United States Geological Survey. The following table is compiled from government records, that portion from 1905 to 1912 having been taken from United States Geological Survey Bulletin 574, (p. 139), and the remainder compiled from "Mineral Resources of the United States."

Mine production of gold, silver, copper, lead, and zinc, in the Sheridan district, Montana, 1905 to 1930.

Year	Mines Reported		Ore	Gold		Silver[a]	Copper	Lead	Zinc	Total Value
	Placers	Lode Mines		Placers	Lode Mines					
			Short tons			fine ounces	pounds	pounds	pounds	
1905			6,864		$ 40,980	10,358	1,000	78,944	------	$ 51,412
1906			552		22,034	3,917	3,000	8,608	------	25,727
1907			73		3,917	902	------	6,106	------	4,836
1908			702		17,538	4,818	641	364	------	20,192
1909	7	11	421		14,632	2,975	1,069	2,128	------	16,409
1910	8	7	530	(b)	16,432	2,707	3,491	243	------	18,348
1911	7	10	1,055	(b)	18,030	4,343	4,077	19,785	------	21,732
1912	3	10	293	(b)	9,218	2,404	4,596	1,764	------	11,534
1913	5	14	1,964	(b)	7,295[c]	3,256[c]	3,810	------	------	20,644
1914	5	12	905	(b)	17,959	2,315	(c)	37,802	------	20,931
1915	4	20	1,011	$ 1,844	(c)	(c)	(c)	(c)	------	30,292
1916	4	15	570[c]	(b)	10,835[c]	1,199	13,029	64,968	2,642	21,027
1917	1	13	416[d]	(b)	5,285[d]	1,769[d]	368[d]	164,118	------	20,957
1918	4	18	4,108	1,342	10,374	6,884	42,738	189,355	------	42,600
1919	1	12	1,465	(b)	10,825	9,455	25,313	37,015	------	28,085
1920	2	10	382[d]	(b)	1,781	6,378[d]	1,396	111,121[d]	------	17,881
1921	2	10	769	(b)	9,387	456	203	------	------	14,023
1922	2	5	(e)	(e)	(e)	(e)	(e)	(e)	------	(e)
1923	2	10	1,140[c]	(b)	11,369[c]	2,977[c]	7,876	------	------	15,754
1924	0	5	694	------	5,591	1,318	1,391	21,369	------	8,366
1925	4	13	1,899	859	6,866[r]	6,182	62	83,312	106,512	27,368
1926	1	12	3,936	(b)	15,172	12,997	499	207,513	(d)	51,270
1927	2	8	1,404	501	10,565	[r]2,768	83	35,344	------	14,873
1928	1	12	823	407	15,355	4,270	2,177	26,099	11,175	20,769
1929	2	8	3,168[c]	3,103	5,941[d]	6,433[d]	12,219	100,374	4,174	21,222
1930	3	9	3,036	1,610	12,134	4,379	8,115	81,981	19,038	21,161
Totals			38,180	$9,666	$299,515	105,460	137,153	1,278,313	143,541	$567,413

(a) Includes silver from placers, (b) Included under lode mines, (c) Total quantity not recorded but value included in total value, (d) Total quantity or value not recorded, (e) Figures not available.

GEOLOGY

The principal country rocks of the Sheridan region are Cherry Creek gneisses and schists. The occurrence of pre-Beltian limestone is more extensive than in any other section of the Tobacco Root area, and these limestones have been important in localizing ore bodies. The distribution of granite in surface outcrop is limited to several small areas of which the Brandon, Upper Mill Creek, and Upper Wisconsin Creek on A. P. A. Mountain are the most prominent. The presence of numerous pegmatite dikes and sills of post-Cambrian age may be indicative of the proximity of underlying granites in many sections. Dikes and sills which locally affect mineralization are present in Nugget Gulch and Noble Creek. The Noble dike and sill resemble those observed in the upper North Meadow Creek area and both have served as host rocks for important ore bodies. This fact is important in determining the age relation, not only of the dikes, but also of the veins, if it be assumed that the dikes are differentiates from the granite. No important exposures of Paleozoic rocks are present in the Sheridan district.

The feature of most importance in connection with ore deposits in this area is probably the sub-surface relations of the quartz monzonite intrusive. As mentioned above, surface exposures of granite are limited to a few small areas. However, it is probable that both the structural deformation and the source of mineralizing solutions in each of the several mineralized areas are related to underlying or nearby monzonitic masses of local influence and extent. This suggests individuality in each of the several districts, and in a measure precludes correlation between such districts either structurally or mineralogically. The relationship suggests that most of the ore deposits are related to quartz-monzonite masses, although there are several possible exceptions to this rule. The sill-like intrusions so prevalent in the Twin Bridges district are not common in the Sheridan district, except in Nugget Gulch. Certain dikes, as that at the Noble mine, may suggest other mineral sources, but even this dike is probably a differentiate from the quartz-monzonite, and since the ore deposit occurs within the dike, it is later than the dike and probably originated in the deep-seated batholith after its partial cooling. The basic dike of the Horse Creek district in which chromite segregations occur, however, may be earlier than the quartz-monzonite, and the true relationship of these deposits is less clear.

The veins are mainly of the fissure filling type, but in this district, limestone replacements are of great importance. Thus, the ore-shoots of the Red Pine, Sunnyside, Smuggler, Fairview, Tamarack, Broadgauge, Betsy Baker, Goldsmith, Agitator, and many others are within or are controlled by pre-Cambrian limestone members. The veins also commonly show a bedding plane relationship, although some of the important veins, as the Noble, Sheridan, and Grey Eagle vein of the Leiter mine, Red Pine, Smuggler, Goldsmith, and others, are independent of bedding or banding in the gneiss and schist. Some of the mines in which bedding plane veins are important are the Jonquil, Fairview, Belle, Betsy Baker, and Tamarack-Broadgauge in part.

In general, the veins are not related to strong structural fissures, and movement is relatively small. The strongest veins were observed at the Lake Shore, Leiter, Noble, Fairview, Sunnyside, Smuggler, Buckeye (in granite), and Betsy Baker mines. This feature alone is not of great importance, but when coupled with a generous supply of mineralizing solutions, strong structures are most likely to contain large deposits.

Mineralization

The chief hypogene minerals of the Sheridan region are pyrite, arsenopyrite, chalcopyrite, sphalerite, and galena all in a gangue of quartz and rarely siderite. Zonal distribution of these minerals is not well defined except in a few places as along the Noble vein, which trends southwesterly through the Jonquil group, probably into the Fairview ownership. The chief sulphides in the Noble are pyrite and chalcopyrite, although subordinate amounts of sphalerite and galena are present and some siderite occurs in the gangue. In the Jonquil mine, southwest of the Noble, chalcopyrite is practically absent and galena is present in important amounts along with arsenical and normal pyrite. The gold appears to occur with the iron rather than with the galena. In the Fairview mine, still further to the southwest, galena and probably rhodochrosite (now entirely oxidized) are in excess of pyrite. In the Leiter mine, which is probably related to this mineral province, exposures of the sulphide minerals were not accessible to study, but samples from the dumps suggest a pyritic ore with very low amounts of copper, lead, or zinc minerals.

No other grouping of properties is sufficiently localized to permit a study of zonal mineral distribution except possibly the Buckeye and Toledo mines, in or near granite. These occurrences probably represent mesothermal mineralization, but the adjacent Tamarack and Broadgauge and other properties are probably epithermal.

Tellurides are not prevalent but are reported in the Sunlight mine near the head of Indian Creek.

Alteration and Enrichment

The intensity of hypogene alteration in the Sheridan district varies greatly in the different deposits. It has been quite extensive in the Lake Shore (main northeast vein in the lower tunnel), Leiter (Grey Eagle vein), Fairview, Tamarack and Broadgauge, Buckeye, Sunnyside, Smuggler, and Betsy Baker veins. In these deposits it consists generally of sericitization and silicification of the country rock which has been broken down by rather strong fissuring. In the Tamarack and Broadgauge, a light, cellular silicious sinter-like mass containing alunite and fine gold is developed after limestone.

Surficial enrichment is important in most of the deposits and particularly in those wherein no massive sulphide bodies have as yet been disclosed. The early stoping on the Tamarack and Broadgauge was in material of this type. The important production from the Noble, Leiter, Agitator, Belle and many others was probably derived from concentrations of gold in the upper sulphide zone in which the normal gold content of the hypogene or primary sulphide zone is considerably less than in the enriched portion.

DESCRIPTION OF MINING PROPERTIES

Space does not permit complete description of all properties of the district and, therefore, it is intended here to describe only those properties important in the consideration of district genetic relations and the more important recent developments not previously described.

Wisconsin Creek District

The Lake Shore or Gladstone mine.--The Lake Shore or Gladstone mine, at the head of Wisconsin Creek, during recent years has been quite extensively developed and equipped. The property was originally opened by a series of adits on a bedding plane vein striking N. 86° E., and dipping 40° N. A number of small, narrow, high-grade sulphide ore-shoots were disclosed. Subsequent development was directed toward deeper development, at mill elevation of these shoots. This latter work was done mainly by drifting northeasterly on a strong fissure vein striking N. 30° E. and dipping 80° W. Upon completion of this work, the property was abandoned, and although the workings are not now accessible, it is said that the results were not satisfactory.

Leiter mine.--Two veins, the Grey Eagle, striking N. 70° E. and dipping nearly vertical, and the Sheridan, striking N. 25° E. and dipping steeply to the east, are developed in this formerly very productive property. From best information available, the important production was from the Sheridan vein just south of its intersection with the Grey Eagle vein. Commercial sulphide ore is reported to be present in the deepest shaft development but this material could not be successfully handled by the cyanide mill on the property.

A recent attempt to reopen this property by means of a long tunnel at mill elevation was not completed, probably because of inadequate financing.

Noble mine.--The Noble mine, formerly productive under the name of the Company mine, has been idle for a number of years. The vein, which strikes N. 30° E. and dips 45° westerly, is opened by a series of upper tunnels and a 2,700-foot lower tunnel. The most productive portion of the vein appears to be in a trachyte dike which in its westerly limits, becomes sill-like.

The ore consists of auriferous pyrite and chalcopyrite in widths averaging about four feet. Many people familiar with the property believe the gold content of the deeper base ores sufficiently high to permit commercial extraction if treated by proper milling equipment, but inaccessibility prevents verification of these reports.

Jonquil mine.--The Jonquil mine appears to be on the south extension of the Noble vein. In the Jonquil, the vein is entirely within the Cherry Creek gneiss and schist. The vein was opened by a series of adits, and some stoping was done in the upper workings. The most recent work, directed to develop below the old stopes, has opened several short, narrow sulphide ore-shoots. The gold content which is quite high, appears to be associated with pyrite rather than with galena, an important sulphide constituent.

Fairview mine.--The Fairview mine is near the intersection of Wisconsin Creek and Noble Fork. The ore deposit, which appears to be along a south continuation of the Noble vein, is, however, associated with a limestone member in the Cherry Creek series. The vein is opened by a series of adits and shafts and present operations are confined to stoping from a shaft connected to the middle tunnel. The mining widths range from several inches to more than five feet, and the shipping ore is very irregular and lens-like in occurrence.

The primary ore consists mainly of pyrite, galena, and probably rhodochrosite (now altered to pyrolusite). Gold enrichments have been produced in the oxide zone through the action of meteoric waters. Developments to date have not disclosed any extensive commercial bodies of sulphide ore and the chief resource of the property lies in extending the limits of the enriched bodies.

Indian Creek District

Red Pine mine.--Development at the Red Pine mine on Indian Creek has been confined to a fissure vein striking N. 25° E. and dipping 50° W. The vein cuts beds of the Cherry Creek series. These latter strike nearly north and south, but the dips differ greatly in this area. In general, the ore-shoots follow the limestone members where cut by the vein, and this relation as far as developments have been completed gives the ore-shoots a northeast pitch. Two shoots, each slightly under 100 feet in length have been extensively stoped above the main tunnel level. These stopes have produced only oxidized ore, and to date development of the deeper, primary sulphide zones by a 1,700-foot crosscut tunnel 400 feet below the main tunnel has not been successful. In the lower tunnel, two veins were cut and a small amount of drifting completed on both. One of these probably correlates with the Red Pine vein disclosed in the upper workings.

Mill Creek District

Buckeye mine.--The Buckeye mine is at Brandon, near the mouth of Mill Creek. The mine is opened by two adits, the lower of which has been extended more than 600 feet as a drift on the vein trending N. 30° E. and dipping 20° to 35° W. The Buckeye vein, so far as developed, is entirely within the Brandon granite, although the contact between the granite and the Cherry Creek series lies roughly parallel to it, and only 70 to 80 feet in the hanging wall of the vein.

The Buckeye fissuring is quite strong and comprises a series of strong faults throughout a zone thirty feet or more in width.

The mineralization is of the replacement type, and its hypogene constituents include auriferous pyrite, argentiferous galena, sphalerite, and chalcopyrite disseminated with quartz throughout the wide fissured zone. Alteration, both by hydrothermal and meteoric solutions, has been intense, although in the developed portions the evidences of surficial alteration are more apparent. The sulphides have been highly weathered and remain only as scattered unaltered residuals.

Recently, a portion of the Buckeye ore body was stoped and concentrated at the Buckeye mill, but because of the collapse of metal prices, the operation was discontinued.

Toledo mine.--The Toledo mine occurs in gneiss and schist, a short distance northeast of the Buckeye and may represent in part the continuation of the Buckeye vein. The ores of the Toledo are similar in character although they contain less copper. The narrow vein widths and the low metal content were prohibitive to successful operation on the large scale undertaken.

Tamarack and Broadgauge.--A complex system of fissures is disclosed in the various workings of the Tamarack and Broadgauge group of claims. In general, the fissures show bedding plane relationship and appear to be controlled by the incompetent physical characteristics between the limestone beds and the gneiss members of the Cherry Creek series. The more important vein structure lies along the gneiss-limestone contact or entirely within the limestone. Faulting has further complicated this already complex system.

The principal mineralized zone has been opened by a series of three adits all connected by an incline winze from which one intermediate level has been opened. The major development has been confined to a vertical depth of 140 feet which corresponds to about 400 feet on the dip. In all these workings only oxidized ore is exposed.

The mineralization is rather unusual for the district and has resulted in very fine-grained free gold in a sinter-like quartz alunite replacement of limestone. Alteration attendant to mineralization is extensive and is represented by highly silicified and alunitized bodies in the limestone. The commercial ore bodies are lensy, pipe-like, and typical of limestone mineral zones.

The production from the property has been quite important, particularly in the old surface enriched zones mined. From the best records available, Mr. A. Leggat, the owner, estimates a production well in excess of $200,000 from this source. In later years, the deeper operations have been intermittent but the present operators plan to maintain a small production on high-grade milling ore.

Smuggler mine.--The Smuggler mine, about seven miles from Sheridan, on Mill Creek, is opened by an adit level for a distance of 700 feet along the vein. In addition, 250 feet of drifting have been completed from a 90-foot winze level.

The Smuggler vein, occupies a strong fault zone which strikes N. 75° W. and dips 70° to the south. The vein cuts beds of the Cherry Creek series which strike N. 20° E. and dip 70° to the west. The vein is strong and the commercial ore bodies occur in shoots which do not appear to be greatly influenced by the character of the country rock. Stoping is carried in widths up to ten feet, and the oxidized ore is milled on the property.

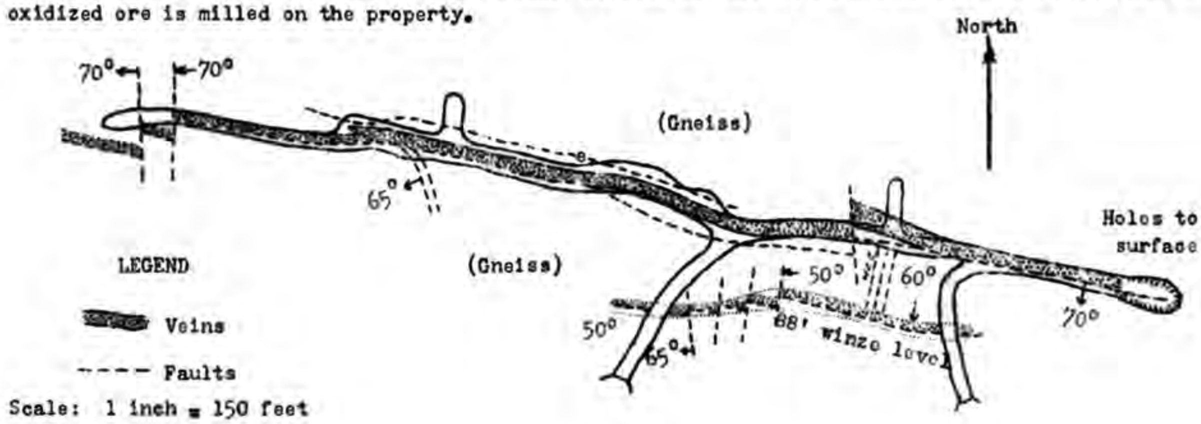


Figure 20.--Composite geologic level sketch, Smuggler mine, Sheridan district.

The character of the primary minerals cannot be definitely determined due to the relatively shallow depth of present developments, although the vein contains disseminated pyrite, as disclosed in the winze level outside of the oxidized ore-shoots. The entire vein structure exhibits strong hypogene as well as supergene alteration.

The drifts from the winze level have not been sufficiently advanced to develop the entire ore limits opened in the main tunnel, and stoping from the lower work has advanced only a short distance above the sill: these factors indicate a fairly certain ore reserve for the immediate future. Additional longitudinal development beyond present explored limits may develop additional ore.

Sunnyside mine.--The Sunnyside mine is at the head of Cow Creek, a tributary to Mill Creek. Limited tunnel development discloses at least two strong veins, the more important of which strikes N. 60° W. and dips 35° northerly. This vein definitely cuts vertical beds of the Cherry Creek series which strike north. The important ore concentrations occur at the intersection of this vein and a vein which strikes N. 30° W. and dips 35° westerly. The significance of the occurrence of a limestone bed at this point is not wholly apparent, but it probably has served as a highly replaceable host rock. Pyrite and galena are present in the lowest vein exposures.

Milling ore below the vein junction appear to be the main resource of the property, but good future possibilities also lie in longitudinal extensions of the veins exposed.

Belle mine.--The Belle mine is several hundred feet above the valley at the head of Mill Creek. The Belle vein, which strikes N. 30° E. and dips 40° to 60° westerly, is parallel to the banding of the gneiss country rock. The vein has been opened along its strike for a distance of nearly 1,000 feet by a series of short crosscut adits from which drifts were extended.

The vein is persistent and uniform although rarely exceeding 12 inches in width. The richer gold ore occurs in shoots in the oxidized portions, but the deeper work has exposed sulphide ore which in general has not proven commercial.

In these upper reaches of Mill Creek, several other properties were partially opened in former days. At present, renewed activity is being centered on the Red Bird and one other property just north of the Belle mine. Conditions in general appear very favorable for the existence of small valuable oxide ore-bodies in this area, and also the sulphide ores, if found with sufficient width, may prove of importance. The occurrence of granite in the upper Mill Creek section further indicates that the area is promising.

Ramshorn District

Betsy Baker and adjacent properties.--The Betsy Baker mine is near the head of Ramshorn Creek. The vein, a bedding plane deposit, strikes N. 10° E. and dips 45° W. It occupies a limy shale member in the Cherry Creek series, and averages 20 to 30 feet in width. Although the vein has been fairly well developed by a series of adits, very little of this work is now accessible. By inference from the material on the dumps, the entire mass is probably well mineralized with sulphides. Shipping ore was probably obtained only in the oxidized portions.

On the north end of the claim, a strong east-west vein dipping 70° S. is exposed in three crosscut adits, and three independent leasing operations are at present being conducted thereon. The vein is narrow but fairly uniform, and ore-shoots with a west rake appear related to a limestone member intersected. The shipping ore obtained is auriferous pyrite with galena and silver minerals in white quartz.

Agitator-Concentrator group.—The Agitator vein, which is developed by a series of adits, strikes N. 10° E., dips 55° westerly, and in general is parallel to the beds of the Cherry Creek series. The vein is in a strong fault zone, some faulting being apparently post-mineral, as evidenced by the small lens-like masses of oxidized siliceous ore in the faulting zone. This oxidized material constitutes shipping ore when present in mineable quantity. One lease is active on the Agitator at the present time.

SUMMARY AND FUTURE OF THE SHERIDAN REGION

From the foregoing descriptions of properties in the Sheridan region, it is apparent that few large occurrences of milling ores are present. The general type of ore deposit is small, narrow, short-length, ore-shoots consisting of enriched oxidized material most suitable for extraction and shipping by lessees. This does not preclude the presence of milling resources, but does suggest that recognition of the general character of the known deposits will permit the best return from operations on a conservative leasing basis. Ultimate development may open important milling resources, but a revision of operating policy may well be postponed until that time.

Too much stress cannot be laid on the necessity of encouraging leasing operations if the production of the district is to be improved or even maintained. This implies that lease royalties should be at a minimum, as high royalty leases will be acceptable only to inexperienced operators. Failure of a leasing operation detracts from the apparent worth of a particular property, and owners should protect themselves against this danger by assisting the lessees in every reasonable manner.

VIRGINIA CITY REGION

The Virginia City region lies near the head of Alder Gulch and is herein considered to include the Alder Gulch, Browns Gulch, Granite Creek, Fairweather, Highland, Pine Grove, Williams Gulch, and Barton Gulch districts.

The discovery of gold in Alder Gulch in 1863 marks the beginning of mining activity in Madison County. Quartz lodes were soon discovered and by 1870 the Oro Cache, Kearsarge, Keystone, Pacific, and other important mines were being operated.

Available statistics of the production of metals from the Virginia City region are not complete, and estimates as to the quantity of gold produced from Alder Gulch and nearby mines vary widely--from $30,000,000 to $150,000,000. The figures given for the early day production in the following table are conservative estimates based on data published by the United States Geological Survey. Statistics from 1913 to 1930 inclusive were compiled from the "Mineral Resources of the United States."

Mine production of gold, silver, copper, and lead in Virginia City district, Montana, 1863 to 1930.

Year	Mines Reported		Ore	Gold		Silver	Copper	Lead	Total value
	Placer	Lode mines		Placers	Lode mines				
			short tons			fine ounces	pounds	pounds	
1863-1866				$30,000,000					$30,000,000
1867-1890				10,000,000	$1,000,000				11,000,000
1891-1903			38,191	2,750,000	269,256	517,631			3,363,240
1904			8,475	278,843	87,088	98,764			423,214
1905			6,814	271,258	68,507	67,792			381,118
1906			4,961	391,044	51,824	80,329	9,902	4,415	499,476
1907			994	195,699	36,679	51,458	9,902	4,415	268,594
1908		5	1,164	414,939	19,063	8,807	116	------	438,715
1909		15	7,930	427,927	36,598	59,832	4,773	------	523,467
1910	5	14	12,641	466,222	131,000	112,000	1,847	14,533	648,534
1911	8	25	9,595	582,055	110,974	77,707	4,015	------	734,715
1912	9	32	2,419	687,863	12,856	14,371	1,330	24,480	745,651
1913	11	27	5,843	689,499	66,829	60,822	2,463	57	793,448
1914	6	19	12,620	835,479	102,150	155,984	2,102[a]	------	1,024,212
1915	5	26	4,447	860,686	(b)	7,234[c]	(b)	(b)	939,806
1916	4	16	329	644,213	(b)	4,864[c]	(b)	(b)	671,032
1917	3	15	921	(b)	5,012[a]	10,535[a]	3,923[a]	522[a]	436,202
1918	3	10	1,867	334,750[a]	15,930[d]	19,304	224	173	370,051
1919	2	14	1,722	265,521	8,114	14,643	697	342	290,283
1920	2	10	471	255,700[e]	4,995	10,219	303	251	271,909
1921	2	8	4,420[a]	190,454	40,060[a]	22,746[a]	510	20,727	254,259[a]
1922	4	9	13,150[a]	37,570	40,129[a]	27,586	4,385	9,229	106,385[a]
1923	6	8	650[a]	13,814[f]	11,399	------	94	------	25,351[a]
1924	5	12	1,146	4,864	8,765	4,820	86	142	16,881
1925	5	9	1,754	8,874[e]	11,857	6,759	50	1,333	25,544
1926	2	10	673	952[e]	6,743	3,725	59	1,306	10,133
1927	2	7	584[a]	363	4,477[a]	9,178	19	4,924	10,356[a]
1928	3	4	18[a]	2,697	724[a]	500	------	2,697	3,765[a]
1929	3	4	87[a]	600[f]	6,101[a]	3,640[a]	2,719	------	10,020[a]
1930	2	6	363	(g)	7,371	4,735	1,293	1,768	9,450
Total			144,249	$50,611,886	$2,164,501	1,455,985	50,812	91,314	$54,296,081

(a) Figure incomplete, (b) Separate figure not available but is included under total value, (c) Silver from placers only, (d) Includes some placer production (gold and silver), (e) Estimated from known data, (f) Includes some silver, (g) Included under lode mines.

GEOLOGY

The general geology of the Virginia City area has been outlined in a preceding chapter. Those features directly related to the ore deposits are briefly summarized to include essentially a province comprised of pre-Beltian gneisses and schists penetrated by only one major granite differentiate, an alaskite dike in the upper Browns Gulch area. The later basaltic extrusives capping uplands east of Virginia City bear no important relation to the present discussion, except in connection with a possible influence on the effect of erosion and enrichment processes of veins underlying this capping. The presence of limestone beds in the gneiss is less important than in the Sheridan district, although the Paleozoic limestones of the Baldy Mountain area probably served as an important host rock for numerous high-grade ore lenses, which through erosion, gave rise to much of the Alder Gulch placer gold.

The ore deposits of the Virginia City district occur in fissure veins. In some places a number of closely spaced, small parallel veins constitute an ore body, but these occurrences are not common.

The usual host rock in the area is gneiss and schist. One important vein system, the Easton-Pacific, occurs in an aplite (alaskite?) mass which penetrates the gneiss and schist in a lenticular form.

The vein system may be classified roughly into two groups, northeast and northwest trending veins. Members of both systems usually dip to the north, and are commonly independent of bedding planes or banding in the gneiss and schist. Some of these veins are traceable by development many hundreds of feet. Some of the more important vein systems are classified as follows:

Classification of some of the Virginia City vein system

Name	Angle of Dip	Chief primary minerals	Principal development
VEINS STRIKING NORTHEASTERLY			
Bamboo Chief-Alameda-Wakoosto	40° N	Auriferous pyrite	Alameda mine
Homestake -El Fleeda-U. S. Grant	40° S	Auriferous pyrite	El Fleeda and U. S. Grant mines
Marietta-High Up-Dorsey	70° N	Auriferous pyrite	Barton Gulch and Greenback mines
Irene	70° N	Auriferous pyrite	Greenback mine
Kearsarge	70° N	Auriferous pyrite (oxidized)	Kearsarge vein
Batten Brothers	Several veins opposite dips	Auriferous pyrite	Batten Brothers mine
Fortuna	65° N	Sphalerite, chalcopyrite, galena, pyrite	Cook or Fortuna mine
Mt. Chief and Mt. Flower	35° N	Quartz limonite after pyrite	Smith mine
VEINS STRIKING NORTHWESTERLY			
Mapleton	70° N	Gold quartz	Mapleton mine
North End - Prospect-Excelsior	60° N	Auriferous pyrite	Prospect mine
Easton-Pacific	70° N	Argentiferous and auriferous pyrite Arsenopyrite	Easton-Pacific mine
Bell-Grand Union	Irregular vein intersections	Auriferous pyrite	Bell mine
Winnetka	50° to 60° S	Free gold after Auriferous pyrite	Winnetka mine
Native Silver	55° N	Auriferous pyrite, Argentiferous Galena	Gardner mine

Classification of some of the Virginia City vein system - continued

Name	Angle of Dip	Chief primary minerals	Principal development
VEINS STRIKING NORTHWESTERLY - CONTINUED			
Black Eagle	77° N	Argentiferous Galena	Gardner mine
Fortuna Lode (main stopes)	65° N	Galena, sphalerite chalcopyrite Auriferous pyrite	Cook or Fortuna mine

Locations of the above structures are indicated on the accompanying map. (See pl. 1.)

The hypogene or primary minerals consist chiefly of quartz and the sulphides, pyrite, galena, sphalerite, and chalcopyrite. Auriferous pyrite or arsenical pyrite are the chief sulphide minerals in the Prospect, Easton, Bell, Cook, Batten, Marietta, High Up, U. S. Grant, and Alameda mines. Galena is important in the Cook, Black Eagle, and Native Silver Properties. Sphalerite is present in considerable amount only in the Cook mine. For a complete detailed description of mineralogic composition of these deposits, reference is made to U. S. Geological Survey Bulletin 574, by A. N. Winchell.

The alteration attendant to mineralization is not intense in any of the properties inspected. The veins are usually narrow and the adjacent walls are not heavily altered or mineralized. Surficial enrichment is of major importance in causing commercial concentrations of gold even where the hypogene mineralization has not proven to be of economic importance. Enrichment ore bodies were of great value in the Winnetka, Easton-Pacific, Prospect, Mapleton, Kearsarge, Oro Cache, El Fleeda, Alameda, and other mines.

The factors bearing on the origin of the ore deposits in the Virginia City area are not clear, but the occurrence of the Easton-Pacific mines in an aplitic differentiate from the quartz-monzonite magma suggests a possible relationship. No other monzonite or monzonite derivatives crop out in the district. It is probable, however, the pre-Cambrian rocks of the region are underlain by monzonitic rocks which are responsible for much of the fissuring and mineralization of the area.

In future developments, attention should be first directed toward longitudinal exploration along the stronger veins in the hope of discovering new high-grade enrichments; and, secondly, deep exploration directed toward the development of commercial base or mill ores should be confined to strong, continuous veins heavy in auriferous pyrite. In the latter procedure, it would be well to remember that primary ore of this type in general does not improve in value with depth.

DESCRIPTION OF MINES

Browns Gulch District

Easton-Pacific mine.--In point of production, the Easton-Pacific group is by far the most important 'quartz' property in the Virginia City district. Judging from the accompanying longitudinal sections (see pl. 5, A), and assuming stope widths of from 5 to 15 feet, at least 100,000 tons of ore was mined from the Easton mine alone.

The Easton-Pacific mines occur in an aplite intrusion in gneiss, and are evidently along the same vein which trends N. 45° W. and dips 70° to 80° southwesterly. The development was conducted in two units, the Easton-unit and the Pacific unit. In the Easton, the vein was opened by three tunnels, one at the creek level and the upper tunnels at 90 and 110 feet respectively above the main tunnel. Near the portal of the lower tunnel, but 40 feet in the foot wall, a shaft was sunk vertically 250 feet and levels opened at 90, 170, and 250 feet respectively below the collar. From the 250-foot level, at a point 300 feet southeast of the shaft, a winze was sunk 200 feet on the vein. In general, all the development was directed southeasterly from the shaft.

Details of the Pacific mine development are not available; however, the important openings were by adits advanced northwesterly from the gulch. Ore mined was hauled a short distance to a transfer raise driven from the main Easton adit at mill elevation 1,280 feet from the portal.

In the Easton mine, two main ore-shoots were exploited, one averaging 250 feet in length and the other, more irregular, averaging nearly 200 feet in length. The deepest stoping was done on the west ore-shoot to a depth of approximately 700 feet below the surface.

The character of mineralization in these properties could not be observed underground, but inspection of dumps and study of mill records indicate the primary ore to be auriferous sulphides in quartz. (Winchell, in U. S. G. S. Bull. 574, reports antimonial silver sulphides in the Pacific mine.) The ratio of silver to gold was higher in the Easton than in the Pacific. It is also reported that the silver to gold ratio increased notably in the deepest workings.

The future of the mine is rather indeterminate, because of incomplete records of the last stoping and lower level work, but according to statements by men most familiar with the later work, additional commercial ore is believed to exist in the mine. However, it would appear that the price of silver will have an important bearing on any future activity at the property.

Barton Gulch

Greenback mine.--The Greenback mine is developed by several adits; one, the main or mill tunnel, prospects the vein for approximately 1,500 feet. The latest work, below the main tunnel, was completed in 1930.

In general, the vein is continuous but narrow, and is mineralized by quartz and sulphide. The important sulphide, pyrite, is auriferous and the silver to gold ratio is about 7 to 1 by weight.

Considerable material was stoped and milled, but the narrow mining width and value of the ore were insufficient to permit a continued profitable operation.

Marietta mine (Barton Gulch Mining Company).--The Marietta mine resembles the Greenback in all characteristics and probably in part represents a continuation of the same vein. Here again, the property was well developed and equipped, but did not appear capable of maintaining continued profitable operation.

Alder Gulch

Winnetka mine.--The Winnetka mine, which is being operated at the present time (1932), is developed by a series of adits and is equipped with a small mill.

The vein is in a fissure striking N. 75° E. and dipping 50° to 60° S. The fissure cuts gneiss and schist. The mineralization resulted in quartz and disseminated pyrite, and the commercial gold ore occurs in west pitching shoots or chimneys in which the gold was concentrated after the decomposition of auriferous pyrite by surficial alteration. In general, the mineralized area is lens-like and gives rise to irregular shoots which under careful development and mining supervision may be expected to yield a moderate return.

Prospect mine.--The well-known Prospect vein, about one mile west of Virginia City, is being exploited by the Virginia City Gold Mining Company. This organization is well financed and with a thoroughly modern 60-ton flotation mill, is ready to begin an active mining program.

The ore occurs in a strong vein striking northwest and dipping steeply eastward. At the surface the vein may be readily traced over the full length of the Prospect claim. It ranges in width up to seven or more feet and is little disturbed by faulting in its developed extent of more than 1,000 feet. The primary ore consists of quartz, galena, chalcopyrite, and pyrite. Galena is the most important primary gold carrier although in the oxidized and secondary zones, gold occurs in jasper and secondary sulphides, particularly chalcocite. The primary pyrite is not an important gold carrier.

From data secured during a study of ore from the Prospect mine by the Ore Dressing Laboratories at Montana School of Mines, the following information regarding the nature of the ore is in part derived

"Polished" briquettes were made of minus 100 to plus 270-mesh flotation concentrate and studied by reflected light at a magnification of 588 times. The principal object of the microscopic study was to determine (1) the degree of locking and the fineness of the gold, (2) mineralogic occurrence of the gold. Approximately 550 particles of free gold and particles of gangue or sulphides containing locked gold were counted and tabulated.

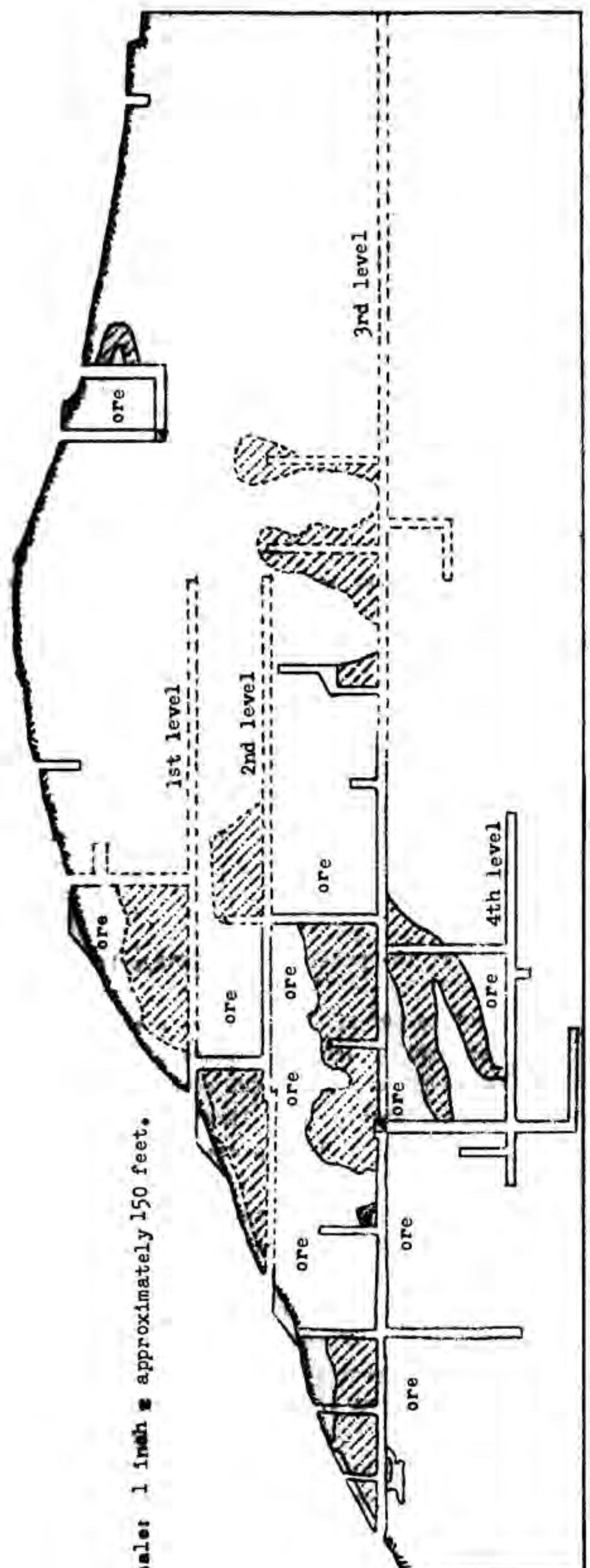


Figure 21.--Longitudinal projection showing stopes on the Prospect vein, Prospect mine. Inaccessible workings are shown by dotted lines and stopes by shading.

"Minerals identified were quartz, jasper, pyrite, galena, sphalerite, chalcocite, bornite, covellite, chalcopyrite, 'gray copper', native copper, malachite, cerussite, native silver, magnitite, hematite, limonite, and native gold.

"In the oxidized zone gold was locked with quartz of jasper. Some sulphides were observed in oxidized ore but gold was not found in these sulphides. In the sulphide zone about one-fourth of the locked gold was found to be tightly interlocked with quartz and about three-fourths of the locked gold was included in sulphides in order of importance as follows: galena, chalcocite, covellite, sphalerite, chalcopyrite, and pyrite. Gold interlocked with sphalerite, was not important and in only one particle was gold found to be locked with chalcopyrite and with pyrite. In fact, it is altogether possible that the particle apparently showing gold locked with pyrite merely represented two particles close together and that they were not actually interlocked.

"Incidental to the counting of locked gold particles it was noted that copper sulphides, mainly chalcocite, bornite, and covellite, replaced pyrite; galena replaced pyrite; and chalcocite replaced galena."

The mine is well developed and can keep the present mill supplied with ore. Much milling ore is available above a main working tunnel. Excellent hoisting facilities, coupled with an absence of water in sub-level workings, points to economical deeper operations.

Since the development on the 100-foot sublevel (approximately 300 feet below surface) discloses an important body of galena-quartz ore which is probably a primary ore, the future development of this property is expected to add materially to its resources.

DISTRICT SUMMARY

Descriptions of the other properties of the district are similar to those considered above. In general, the surficially enriched zones offer the greatest promise of commercially valuable ores. The hypogene ores have not proven to be of great value in any of the developments to date, the chief negative factors being the narrow widths of the ore-shoots and the low proportion of auriferous pyrite.

N O R R I S   R E G I O N

The Norris region includes the Upper and Lower Norris Basin districts, the Sterling district, and the Revenue district. The relative position of these areas is indicated on the accompanying geological map. For convenience the ore deposits of the Washington district are included under the general heading of the Norris district.

HISTORY AND PRODUCTION

Quartz mining in the Norris district followed the discovery of placer gold in Norwegian Creek and Meadow Creek in 1864. Winchell, in U. S. G. S. Bull. 574, states that by 1869, eight mills were in operation in the area. During the seventies, the Handricks, Red Bluff, Rising Sun, Boaz, Galena, Pine Tree, Sterling, and Stevens mines were active. During the eighties activity ceased in the Red Bluff mine when a heavy flow of water was encountered. The Revenue, Monitor, and Galena mines were brought into production in the late nineties. Since 1900, the Missouri-McKee mines are the most important discoveries.

Reasonably accurate estimates of production in the Norris district prior to 1902 are extremely hard to get. In the following statistical table, the figures for production prior to 1902 are Winchell's estimates; from 1902 to 1912 inclusive also from Winchell's report; and from 1912 on, have been compiled from the 'Mineral Resources of the United States.'

Mine production of gold, silver, copper, and lead in the Norris district, Montana, 1864 to 1930.

Year	Mines reported	Ore	Gold	Silver	Copper	Lead	Total Value
		short tons		fine ounces	pounds	pounds	
1864 to 1901							$3,300,000[a]
1902		2,022	$107,580	7,862	9,000	5,680	112,622
1903		153	8,093	300	------	------	8,243
1904		3,316	30,040	2,657	10,000	726	35,589
1905		10,779	147,239	27,115	7,877	38,843	166,821
1906		497	31,018	2,867	------	15,513	33,823
1907		781	17,777	4,522	260	------	20,833
1908		666	17,055	1,704	1,341	2,240	18,223
1909	19	2,886	27,071	1,722	1,045	------	28,102
1910	14	1,602	11,723	1,510	127	4,706	12,761
1911	22	719	17,145	5,018	740	3,823	20,069
1912	15	472	16,262	1,540	883	901	17,396[b]
1913	18	701	3,721	181	(f)	1,278	33,904[d]
1914	13	1,456	77,065	10,886	------	------	86,607[d]
1915	16	1,161	(e)	(e)	(e)	(e)	9,796
1916	6	163	4,258	385	1,420	(e)	8,098[d]
1917	13	93	3,664[f]	394[f]	887[f]	------	7,105
1918	4	(g)	(g)	(g)	------	------	(g)
1919	11	79[f]	2,023[f]	1,255[f]	(e)	------	3,499
1920	6	(g)	(g)	(g)	------	------	(g)
1921	9	(g)	(g)	(g)	------	------	2,895
1922	6	1,124[f]	11,886[f]	1,042[f]	------	------	12,928
1923	8	1,000[f]	(g)	(g)	------	------	1,389
1924	10	201[f]	3,494[f]	712[f]	(g)	------	3,971
1925	10	(g)	(g)	(g)	------	------	1,423
1926	10	(g)	2,454[f]	312[f]	------	159[f]	2,662
1927	9	1,019[f]	12,387[f]	1,038[f]	92[f]	1,530	13,497
1928	4	141[f]	885[f]	42[f]	------	198	921
1929	7	61[f]	1,298[f]	19	------	57	1,312
1930	6	(g)	(g)	(g)	------	------	(g)
Total Value							$ 3,964,489

(a) Includes \$300,000 from placers, (b) Winchell's figure of \$13,738 is evidently a typographical error, (d) Total value incomplete, (e) Quantity not recorded but value included in total, (f) Total quantity nor value recorded, (g) No figures available.

GEOLOGY

In a broad sense, the rocks of the Norris district may be grouped into two classes: pre-Beltian gneiss and schist, and quartz-monzonite (granite) of late Cretaceous age. The granite occurs as a continuous unit—four miles wide, trending N. 70° W., and originating in an area just south of Norris. A hypersthene gabbro dike which becomes sill-like in the upper North Meadow Creek section is probably a differentiate from the granite, and the acid sill in the Ward Peak area is probably similarly a differentiate.

Ore deposits occur in each of the above described rocks, the greater number being in gneiss and granite. In point of production, the most important property is the Revenue, which is in granite.

In general, all the deposits are believed to owe their origin to a deep-seated source or sources in the granite. In the formation of all the deposits of the area, a structural break or fissure which taps the deep-seated mineralizing sources, either directly or indirectly, must have been present. The producing veins differ considerably in general characteristics in the different sections of the area, being predominately flat and irregular in the South Meadow Creek, Revenue, and Sterling district and strong, steeply dipping fault fissures in the Norris section.

Secondary enrichment has been an important factor in causing commercial gold concentrations, and the true character of the primary ore is rarely determinate in any of the accessible mine workings today. Auriferous pyrite is probably the most widely distributed valuable component of the mineralization, but galena, sphalerite, chalcopyrite, bornite, and chalcocite have been noted in ores from the Frisbie mine, Galena mine, and some of the Norris mines. Zonal relations are not clearly defined, but the scattered distribution of complex relations suggests the probability of several mineralizing centers.

DESCRIPTION OF MINES

Mines Near Norris

Boaz mine:—Two important parallel veins, the Golden Treasure and the Boaz, striking N. 40° W. and dipping 60° northerly, crop out in the Boaz group of claims. A series of drifts and a 150-foot shaft explore the Boaz vein approximately 600 feet longitudinally and 150 feet vertically. The more important production was from enriched bodies in the oxidized zone which extends to a depth of slightly more than 100 feet. The mineralized material below that depth, although partially oxidized to the maximum depths attained, is composed of pyrite and galena in important amounts; and on the bottom level, a ratio of twenty ounces of silver to one ounce of gold has been noted. The vein at this depth ranges from several inches to two and one-half feet in width, and as far as developed no important ore reserves have been blocked out.

The future importance of the property lies in the probability of discovering new enriched oreshoots through longitudinal extensions of development work in the upper levels. Finding of primary sulphide ore depends on the success of exploration work along the vein below the zone of oxidation.

Josephine mine.--The Josephine mine lies parallel and adjacent to the Boaz claim along its south side line. A vein system trends northwesterly, dips 50° northerly and is made up of several closely spaced, parallel fissures of which at least two units have been developed by short drifts and stopes. The more important development has been confined to a hanging wall branch vein, in which a shaft has been sunk 140 feet on the incline. Three drift levels are established at 30 to 50-foot intervals. Workings now accessible permit inspection of the vein over a maximum length of only 200 feet. The vein averages from several inches to three feet in width, and most of the ore is oxidized to the maximum depths attained.

This property is similar to the Boaz in that its future importance depends essentially on the success of longitudinal exploration along the vein in the enriched oxide zone. The future value of sulphide mineralization is indeterminate because of the limited exploration completed in the deeper zone.

Several other properties in the vicinity of the Boaz and Josephine are being intermittently developed and operated. They are all similar in most details. The better known old properties, such as the Red Bluff, are wholly inactive and inaccessible, and no information relative to them is available.

Revenue mine.--The Revenue mine, ten miles southwest of Norris in the Richmond Flat area, includes the Revenue and Monitor groups which are reported to have produced in excess of $2,000,000 in gold. The property was closed down in 1921 and has remained idle since that time.

The Revenue is entirely within the granite. A complex system of intersecting fissures controls the ore deposits. The most important ore body is the Revenue vein, which strikes northeasterly and dips very flatly to the north. The extremely flat dip, ranging from 0° to 12° gives rise to extreme irregularity in strike. A second set of fissures is roughly parallel to the above in strike but dips much more steeply to the north. Six or more fissures of the latter series cut the Revenue vein in the known development and successively step-fault the vein down on the north.

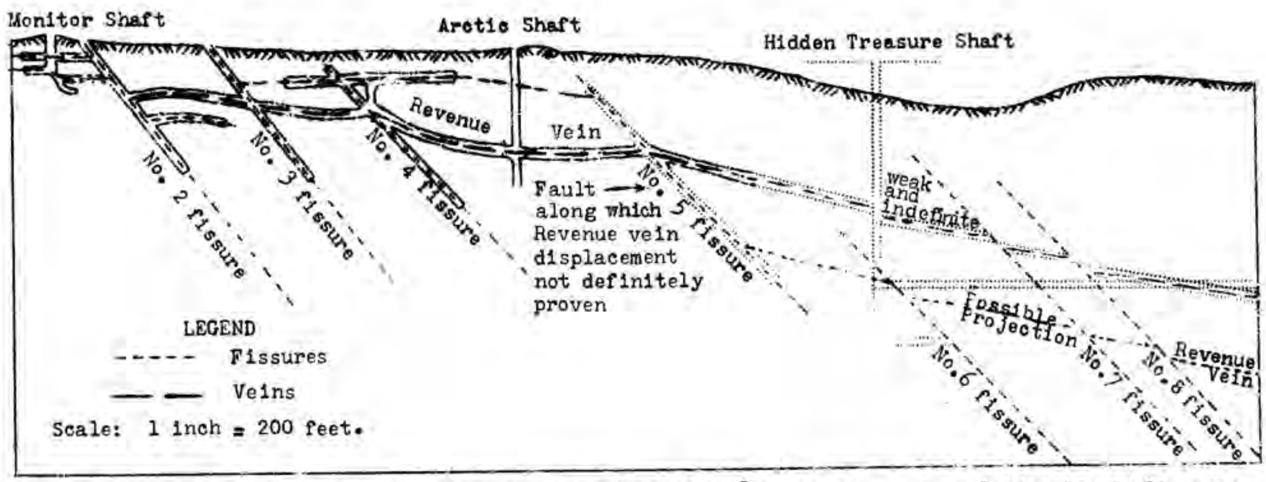


Figure 22.--Section across the Revenue vein on a plane N. 12° W. showing vein relationship to fissures.

The commercial gold ore occurs at or near these intersections, so that the stopes are elongated in a northeasterly direction, but rarely do they extend either up or down the dip of the Revenue vein for a distance exceeding 100 feet. Three major ore-shoots of this type were discovered in relation to three seperate intersecting fissures. Numerous smaller shoots were stoped, but the relation to intersection fissures is not clear. Prospecting down the dip at other points of intersection has been done to some extent without important success. It is not altogether certain that this work recovered the faulted segment of the main Revenue vein, as the vein exposed is much weaker and does not closely resemble the true Revenue vein. This condition introduces an element of hope relative to future possibilities of the property.

The mineralized material exposed at present is essentially oxidized and consists of quartz and limonite with free gold. Sulphides, chiefly pyrite, began to appear in the deeper workings. In general, the commercial ore bodies are believed to result from enrichment processes although the exact relation of intersecting structures is indeterminate. Whether downward migrating solutions derived most of their gold from the Revenue vein or from the cross veins is not certain, but the most probable source is in the Revenue vein. A possible precipitation may have resulted from the intermingling of solutions originating in the two structures with the effected zones being at or near their intersection. In the richer stopes, the gold occurred in sheeting planes in the walls outside the main vein. This permitted stopes widths to reach a maximum of 6 and 8 feet, although the vein itself rarely exceeded 2 to 3 feet in width. High-grade shipping ore was frequently found in the stronger shoots, but the average held closely to $8 to $10 a ton in gold, and the ore required milling at the property.

Although most of the ore bodies were exhausted during the last operation, possibilities of future production still remain in deeper development on the main vein, (assuming that present deep work is not on the main vein), and in general longitudinal exploration directed toward the discovery of new ore-shoots. In connection with the latter, attention is called to the description of the Bull Moose mine.

Bull Moose mine.--The Bull Moose property lies on a probable north extension of the Revenue vein in the region of the old Hawkeye claim. The vein is developed by several shafts from the surface outcrop, from which several hundred feet of drifting, at a shallow depth, have been completed. The vein as disclosed is a strong fissure filled with quartz and pyrite with subordinate amounts of galena. Some of the ore mined was sufficiently high in gold content to permit direct shipment; but most of the ore must be milled.

The development to date does not expose any cross structures and in this respect may be assumed to be outside of the most probable ore zones. A careful study of surface relations might indicate the locus of such intersections and thereby determine promising points for further exploration.

Galena mine.--The Galena mine, at the old town of Sterling, is entirely within granite. Several veins striking N. 40° E. and dipping 30° N. are known, but most of the development, completed from a 30° incline shaft, was done on the Galena No. 1 vein. Full development description is impossible as the mine is inaccessible at present.

Judging from dump material, complex ore containing galena, sphalerite, chalcocite, bornite, and pyrite was discovered at least in the lower workings, but it is quite probable that the greater portion of gold production was derived from upper level, oxidized material.

The future prospects of the property are difficult to determine.

Washington District

The ore deposits of the Washington district include those in the Meadow Creek watershed. This permits a general division of the area into the upper North Meadow Creek, the upper South Meadow Creek, and the lower Meadow Creek areas. The geological conditions in each are quite different so that they are described separately.

Upper North Meadow Creek.--Three general rock types may be observed on upper North Meadow Creek: one occupies the north limit and is composed of granite; another occupies the south portion and is pre-Beltian gneiss and schist; a third is a granite differentiate in the form of a dike which originates in the granite and terminates toward the south as sills in the pre-Beltian rocks. This rock is composed of hypersthene and may be termed a hypersthene gabbro. Most of the ore deposits occur within the gneiss, but those of the Frisbie mine are mostly in the gabbro near its contact with gneiss. A few silver veins are known to cut the granite.

Frisbie mine.--Development at the Frisbie mine is on a series of fissure veins striking N. 10° W. and dipping steeply west. The development work has been done at opposite ends of a small lake, and consists of shallow shafts. The north work is entirely within gneiss at a point not exceeding 100 feet from the gneiss-gabbro contact, and the south work is entirely within the gabbro. A lower tunnel approximately 700 feet long does not disclose the vein, and it is concluded that this work is still short of a probable west projection of the vein zone.

High gold content in complex sulphide ore, containing galena, sphalerite, bornite, and pyrite was disclosed in all the upper workings, but the north work was in more oxidized material. As exposed, strong mineralization in the south work extends over a width of thirty feet.

The limited development completed permits a very indefinite determination of the value of the property. It is clear, however, that the showings so far exposed are exceptionally encouraging and further development of the property is encouraged.

The Kidd mine, about a quarter of a mile southeast of the Frisbie property, is on an explored vein which cuts the gneiss parallel to banding. A mill is installed on the property and although a considerable tonnage of oxidized ore has been treated, the property is now idle.

Lower Meadow Creek area.--The geology of the lower Meadow Creek area is simple and involves only a granite-gneiss contact zone. No important work has been done in the granite and only a few small prospects in the altered, contact gneiss zone are known. Among these, only the Eliot and Moorehead properties are at present active. They are similar in character, and the deposits may be said to expose numerous small quartz stringer veins in gneiss. The vein material as exposed at present is wholly oxidized and it is believed by the owners to constitute a large-tonnage, low-grade gold ore-resource. Development work directed toward determining the value of this property consists essentially of crosscut adits. The rock taken from such development is being treated in mills to ascertain the gold content.

Upper South Meadow Creek area.--In the Upper South Meadow Creek area, an andesite sill occurring in gneiss marks the important locus of ore. The Missouri-McKee group is important in this area.

The Missouri-McKee mines, about eight miles west of McAllister, are at elevations ranging from 9,000 to nearly 10,000 feet above sea level. The country rock consists of hard, crystalline gneiss, into which an andesite porphyry sill has been intruded. The sill, which is approximately 100 feet in thickness, bears a bedding plane relationship to the banding of the gneiss and the dip is generally nearly flat, varying from zero to a maximum of 5° in the McKee and from 10° to 40° in the Missouri mine.

The veins generally follow the contact between the andesite and gneiss. In the Missouri, the major ore zones followed the upper contact, while in the McKee, they followed the lower contact of the sill. Some cross fissuring in the andesite was noted in the Missouri mine.

The ore in both mines is wholly oxidized, and consists of quartz, limonite, and cerusite, indicating derivation from a primary ore composed essentially of galena and pyrite. Gold and silver are associated with cerusite, which indicates their original preference for galena rather than for pyrite. The ore-shoots generally occur in synclines resultant from minor folding of the andesite and gneiss. For this reason, their outline is generally elongated along the axis of the synclines.

Both properties have been rather completely prospected by a series of adits, winzes, and sublevels. A 30-ton amalgamation and cyanide mill connected to the mine by an aerial tramway has been built.

In general, most of the ore in the shoots disclosed in the two mines has been mined and only a small reserve of positive ore remains. The discovery of additional ore will depend largely on a search for entirely new ore-shoots rather than extending the limits of the known shoots. In general, the area presents some promise of new ore bodies. Full recognition of the major features of ore-shoot control, of which the synclinal relationship is most important, should permit elimination of a considerable portion of the area and thereby center any future activities on the more encouraging portions of the mineralized belt.

GENERAL CONCLUSIONS

The following general conclusions may be drawn relative to the Tobacco Root Mountain area as a whole:

1. The ore deposits are predominately gold bearing and are observed to occur in most of the important rock groups of Tertiary or earlier age found in the area.

2. The most important factor influencing the locus of an ore body is believed to be fissuring of sufficient magnitude to tap a deep-seated mineralizing source. This implies that the character of the host rock and the relations of the fissure to physical features of the host rock are of minor importance, and it necessarily assumes that only at points where mineralizing solutions could find access by fissures to overlying rocks could ore bodies of importance develop. Further, the magnitude of the fissure and the intensity of hydrothermal activity determine the size and importance of the resulting ore body.

3. Secondary enrichment has been an important factor in causing high-grade gold concentrations quite generally throughout the area. The occurrence of primary ore of commercial value is best observed in the Mammoth, Boss Tweed, and possibly the Noble mines.

4. The future importance of the district as dependent upon the above general factors may be said to lie in (1) the discovery of new, high-grade enriched bodies near the surface, and (2) the further development of primary ore of milling grade in the known ore bodies by means of conservative and well advised deeper developments.

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