Reconnaissance Geology of Western Mineral County Montana

By ROBERT E. WALLACE *and* JOHN W. HOSTERMAN

A CONTRIBUTION TO ECONOMIC GEOLOGY

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The geologic structure and mineralogy of western Mineral County, Mont., as determined by a series of traverses, are similar to those of the rich Coeur d'Alene mining district

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[Plates are in pocket]

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By Robert E. Wallace and John W. Hosterman

ABSTRACT

Rocks underlying western Mineral County, Mont., are principally metasediments of the Precambrian Belt series consisting of quartzites, argillites, and phyllites. Dioritic instrusive rocks, principally sills, underlie a small part of the area. Pleistocene and Recent sediments, including lacustrine, glacial, and fluvial deposits, overlie some of the area.

A major structural grain that trends northwest and that is made up of subparallel faults and folds characterizes the area. The Osburn fault zone, one of the major faults of the Northern Rocky Mountains province, is the major structure in the area. The fault zone is known to extend from a point near Coeur d'Alene, Idaho, to a point near Superior, Mont., across western Mineral County, Mont. It may extend even farther to the east and to the west. North of the Osburn fault zone in western Mineral County intense structural deformation has produced large overturned isoclinal folds and many large faults. South of the Osburn fault zone folds are relatively open and dips rarely exceed 50°. Faulting is notably less south of than north of the Osburn zone. Evidence suggests that there were at least three periods of deformation each represented by a different stress system: compressional stresses which produced overturned folds and reverse faults, rotational stresses which produced strike-slip faults, and stresses which produced normal faults.

Mineral deposits are principally of lead, zinc, silver, and copper in the form of replacement and fissure-filling veins containing galena, sphalerite, tetrahedrite, and chalcopyrite in a gangue of quartz, carbonate, and in a few places barite. The geology and mineralogy are similar to those in the Coeur d'Alene district, and the two areas should be considered parts of the same geologic district. Production from Mineral County, however, has been extremely small compared to production in the Coeur d'Alene district, but Mineral County has not been so intensively explored as Shoshone County. The amount of vein material and favorable structural settings of several beltlike areas following major faults in Mineral County suggests that much more exploration is warranted.

INTRODUCTION

This reconnaissance study was undertaken to determine the major geologic features of the western part of Mineral County, Mont., principally in the drainage basin of the St. Regis River (fig. 73). It seemed possible that geologic conditions similar to those of the adjacent Coeur d'Alene mining district in northern Idaho, from which more than one billion dollars' worth of metals have been recovered, might extend into Mineral County.

Fieldwork was done in the summer of 1952. The writers spent 20 days making joint traverses by jeep along accessible roads and then 20 days making separate traverses afoot across significant areas. Twelve days were spent mapping accessible underground workings in the area. Most of the underground mapping was done by Hosterman, who was assisted by Earle Cressman.

These reconnaissance traverses formed the basis for the interpretation of the general geologic setting as shown on the map (pl. 48). As there is some uncertainty about the interpretation of the geology of

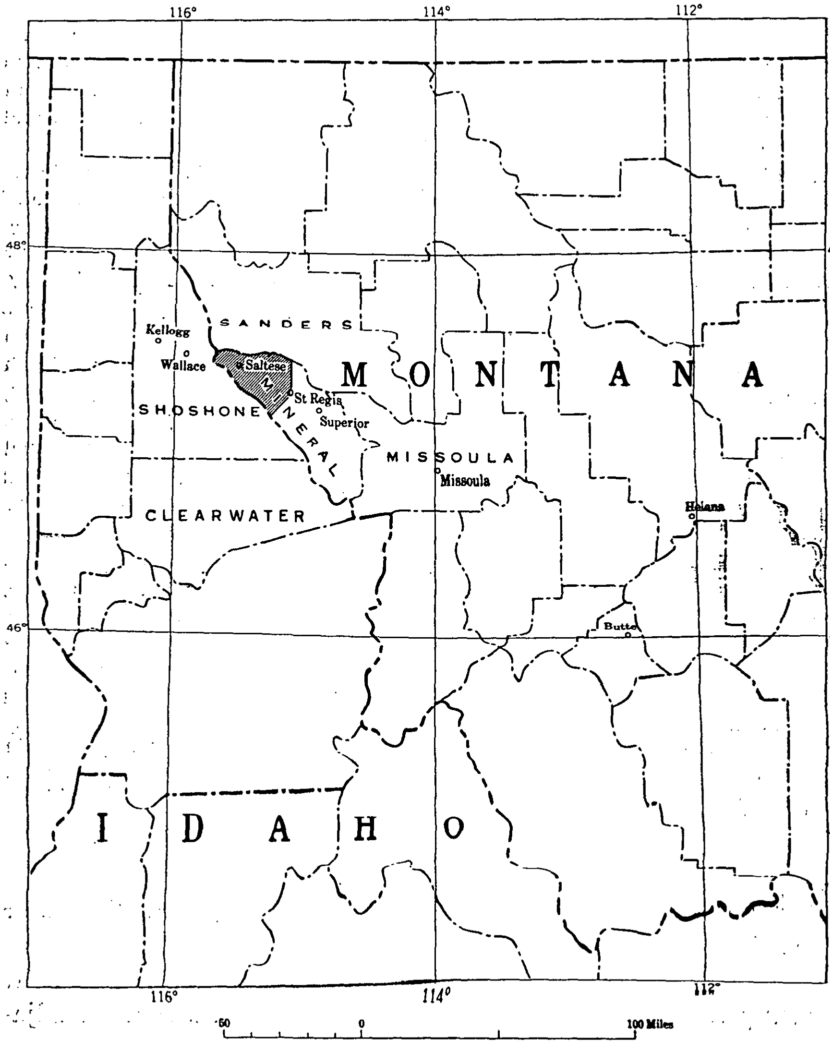

FIGURE 73.—Index map showing location of western Mineral County, Mont.

various parts of the area, an attempt has been made on the map to differentiate recorded data from interpretation by identifying traverse lines with bands of grayed color. Symbols have also been used to indicate different sources of information. For example, much information was derived from the interpretation of aerial photographs, and although many features observed on the photographs can be interpreted with a high degree of certainty, information thus derived is designated by symbols on the map.

The reconnaissance nature of the investigation is indicated by the fact that a geologic interpretation of about 350 square miles of country was made in 60 man-days of traversing, or at a rate of slightly less than 6 square miles per day. The map and report are incomplete in many ways and represent merely what was seen and recorded in a short time.

Because of the intricacy of the structure and the difficulty presented in delineation of geologic formations, many areas will require a more detailed study before an adequate geologic interpretation can be made.

The excellent cooperation of all the mining companies active in the area and the assistance of residents of the area on many occasions are appreciated by the authors.

GEOLOGIC FORMATIONS

GENERAL CHARACTERISTICS

The western part of Mineral County, Mont., (fig. 73) is underlain predominantly by metasediments of the Precambrian Belt series. Rocks exposed in the area include parts of the following formations, listed from oldest to youngest: Prichard, Burke, Revett, St. Regis, and Wallace. Relatively recent unconsolidated sediments cap these older metasediments. The unconsolidated sediments include lacustrine and glaciofluvial deposits of Pleistocene age, and alluvium of Recent age. A small part of the area is underlain by diorite sills and dikes.

The presence of rock units in each formation of the Belt series which resemble rock units in every other formation of the Belt series makes classification of individual outcrop areas difficult. Only by judging the predominent rock type through a stratigraphic thickness of several hundred feet or over areas of several thousand square feet can an adequate determination be made.

The study of 25 thin sections of rocks, including typical specimens from each formation, shows the preponderance of quartzites in this area. Many of the fine-grained quartzites were identified in the field as argillites, but extremely fine-grained quartz is the dominant constituent, and sericite and chlorite are present in conspicuous amounts. Many of the fine-grained quartzites are composed of grains ranging from 0.01 to 0.03 mm in diameter (medium-silt size). The coarsest grained quartzites examined contain grains as much as 1 mm in diameter, but these coarser sizes are relatively uncommon, and grains rarely exceed 0.3 mm in diameter. The quartz grains in most specimens have been recrystallized and their borders at least slightly sutured, but the angular shape of original grains is apparent in many. Some specimens examined are highly sericitic, and a few from the greenish St. Regis strata contain 50 percent or more pale-green chlorite.

In the specimens examined, sericite is the most abundant mineral associated with quartz in samples from the Wallace formation, whereas sericite and chlorite are both abundant in samples from the St. Regis formation. Biotite is abundant in the fine-grained quartzites of the Prichard formation. Plagioclase, apparently as detrital grains, was identified in quartzites from both the St. Regis and Prichard formations. The few grains identified were oligoclase. Magnetite is sparsely scattered through all the formations and is locally concentrated in greater amounts in some thin beds or laminae.

In the following descriptions colors are classified according to the system employed in the "Rock Color Chart" (Goddard and others, 1948) distributed by the National Research Council.

PRICHARD FORMATION

The uppermost 5,000 feet of the Prichard formation is shown in the northeastern corner of the mapped area where it is exposed at the head of Swamp Creek in the overturned flank of the Swamp Creek anticline. No section was measured or studied in detail, but in general the formation is characterized by the dark argillites and fine-grained quartzites, as it is at its type locality. The contact between the Prichard and the Burke and Revett formations undifferentiated is gradational, and relatively light-colored massive quartzites are interbedded with dark thin-bedded argillites and fine-grained quartzites through a stratigraphic range of several hundred feet. Many of the beds in Swamp Creek contain considerable biotite in minute flakes of random orientation. Ripple marks and graded bedding were observed but are not common. Limonite staining on weathered surfaces is characteristic.

In addition, a thick well-exposed section of the Prichard formation a few miles east of the mapped area was studied and is described briefly here in order to give a more comprehensive idea of what the Prichard formation is like in this region. From the junction of the Clark Fork and Flathead Rivers southwest to Paradise Ferry across the Clark Fork River, an air line distance of 5½ miles, an almost continuous section of the Prichard formation is exposed in the canyon walls of the Clark Fork River and in railroad and road cuts along the canyon. In this entire section, except for a minor flexure north of Quinns Hot Springs, dips are uniformly to the southwest and range between 40° and 60°. Discounting unidentified faults, this section is very nearly 17,000 feet thick. A few apparently minor faults were identified northeast of the ferry, and the top of the section is truncated by a major fault. This large fault is believed to be part of the Tamarack Creek-Thompson Pass fault system and is well exposed in road cuts near the mouth of Patrick Creek. The base of the exposed section is at the crest of a major breached anticline that is followed by the Clark Fork River from its confluence with the Flathead River northwestward to the vicinity of Plains, Mont. More than 5,000 feet of section can be seen in one almost continuous exposure southwest of Quinns Hot Springs. The presence of the hot springs suggests a fault in the section, but no lineament suggestive of a fault was observed on the aerial photographs. No field study was made to confirm the presence or absence of such a structure.

Throughout the section the Prichard formation is most commonly characterized by very fine to fine-grained quartzites and by siliceous argillites, with beds from 2 inches to 2 feet thick; colors are medium gray (N3–N5) and greenish gray (5GY 5–7/0.2–1). Pyrite is abundant, and weathered surfaces are typically moderate brown (5 YR 3–4/4). The dark, neutral-gray colors (N3–N5) are as characteristic as any other feature, because in other formations a slight chroma is generally present and darker values are generally absent. Compared to the Prichard formation near Kellogg, Idaho, this section is more uniformly siliceous, has fewer soft argillites, and has fewer thinly laminated argillite beds.

No subdivision of the formation is possible with present data, but two special units are described below.

Exposed near the top of the Clark Fork section are medium-gray homogeneous argillites whose excellent cleavage parallel to their bedding gives them the appearance of slate. The color is typically neutral gray (N3–N4). Pyrite is abundant along bedding planes. Near the middle of the section fine- to medium-grained vitreous quartzites of light greenish-gray (5 GY 7/0.2–1), in beds as thick as 5 feet, make up a unit about 100 feet thick. Thinner units of similar quartzite are present throughout the section. These quartzites near the middle of the section may correspond in a general way to the middle Prichard quartzites of the Kellogg, Idaho, area. This statement does not imply that any one quartzite bed is considered to be continuous over such distances.

BURKE AND REVETT FORMATIONS

In the western part of Mineral County, quartzites, which are presumed to be the equivalent of the Burke and Revett formations of the Coeur d'Alene district have not been differentiated on the map. This was necessary because differences between these formations are much less distinct than in the Coeur d'Alene district where they have been fairly well delineated, and the reconnaissance study did not permit detailed scrutiny of subtle differences that might permit a differentiation of the units in all places. Only on the geologic maps of and in the discussions of the Silver Cable and Last Chance mines are the formations differentiated.

The writers believe that there is a gross lithologic difference between the quartzites of the Burke and Revett formations north of the Osburn fault zone and those south of the fault zone. North of the fault zone, however, tight folding and much faulting make complete analysis of the stratigraphy very difficult. In only a few places was a normal contact found between the quartzites of the Burke and Revett formations and the adjacent formations, and all of these contacts are in the deformed flanks of tight folds. All other known contacts are fault contacts.

South of the Osburn fault zone the quartzites of the Burke and Revett formations are typically fine grained, somewhat argillaceous quartzites, generally a light gray of low chroma or greenish gray (5GY 5-6/1). Bedding thicknesses are usually more than 1 foot and range up to 8 or 10 feet. The most common thicknesses are between 1 and 4 feet. White vitreous quartzites characteristic of the Revett quartzite in the Coeur d'Alene district are rare. Nowhere south of the Osburn fault was the base of the quartzite section of the Burke and Revett formations found, but the top is well exposed in many places. Because the quartzites of both the Revett and St. Regis formations in Mineral County, Mont., are shades of gray, the color distinction commonly used in Idaho between the white quartzites of the Revett and the overlying purplish-gray St. Regis formation is scarcely applicable. In Mineral County a contact between the formations has been chosen so that the principally argillaceous beds are above and the principally quartzitic beds are below the contact. The authors believe that this use of rock type as the diagnostic feature rather than color is appropriate. It should be recognized that on many maps of the Coeur d'Alene district purplish-gray quartzites are classified and mapped as St. Regis formation, but that in Mineral County some distinctly purplish-gray quartzites are included in the Burke and Revett formations.

The quartzites of the Burke and Revett formations are well exposed in road cuts along a 4-mile section of U. S. Highway 10 immediately east of Saltese, Mont., and in road cuts on the same highway in the canyon of the St. Regis River between Henderson and St. Regis, Mont. In the cuts, lithologic units ranging from thick vitreous quartzites to gray argillites are found, but no characteristic gradation in rock type from top to bottom of the section exposed was recognized. At least 3,000 feet of quartzites of the Burke and Revett formations are present in the south flank of the Boyd Mountain anticline. Although 8,000 feet are shown in the structure section, there is almost certainly some faulting which could repeat part of the section.

In the cirques at the heads of Deer, Ward, and Newman Creeks are excellent exposures of the uppermost 1,500 feet of the quartzites of the Burke and Revett formations. The quartzites are predominantly gray and vitreous and are in beds from 1 to 10 feet thick. The contact with the argillites of the overlying St. Regis formation is excellently exposed but is difficult to map because of the gradational character. Through a stratigraphic range of about 400 feet grayish vitreous quartzite beds as much as 1 or 2 feet thick are interbedded with greenish-gray thinly laminated argillites. More detailed study might make it possible to map this as a separate transition unit, but in this reconnaissance the separation of Burke and Revett from St. Regis was made merely by differentiating the principally quartzitic part of the section from the principally argillaceous part of the section.

North of the Osburn fault zone deformation has been so intense that continuous sections of the quartzites of the Burke and Revett formations are rare. Very light-colored thick-bedded vitreous quartzites similar to Revett quartzite in its type locality were found in the vicinity of Mullan Pass, Sawhill, the Silver Cable and the Bryan mines, near Camels Hump Peak, and near the mouth of Tamarack Creek. Greenish-gray (5GY 6/1) thin-bedded impure quartzite similar to quartzite of the Burke formation in its type locality was found in several places. North of the fault shown on the map at the Silver Cable mine the rocks appear to be typical of the quartzites of the Burke formation and at several other places float more characteristic of Burke than Revett was found.

On Mount Bushnell the quartzites include both impure, argillaceous quartzites and some vitreous quartzites. Beds range from 1 inch to 4 feet in thickness, and have abundant mud cracks and ripple marks. They are pale gray to greenish gray. These rocks are probably near the top of the section of quartzites and grade upward into the argillites of the St. Regis formation.

ST. REGIS FORMATION

Mapping of the St. Regis formation in Mineral County, Mont., is complicated by a marked facies change within a distance of 4 or 5 miles near Lookout Pass. West of the State line in Idaho, the St. Regis formation is typically gray to purplish-gray argillite, about 1,200 to 1,400 feet thick, and has an upper member of thinly laminated greenish argillite, 150 to 450 feet thick.

Half a mile southeast of Lookout Pass on U. S. Highway 10 road cuts expose interbedded greenish-gray (5G 6–7/1) and purplish-gray (5P 5–6/0.2) argillites or reddish-gray (5R 6/1) argillites and fine-grained quartzites. Two miles farther southeast of Lookout Pass purplish-gray colors are uncommon and are confined to the more quartzitic beds. The typical color of the argillaceous beds here is a greenish gray. Near Randolph Creek, 5 miles east of Lookout Pass, thinly laminated greenish-gray argillites, typical of the upper member of the St. Regis formation west of Lookout Pass, make up the major part of a stratigraphic section about 3,000 feet thick. Near Silver Creek 3 miles farther east, the section is more than 5,000 feet thick. Near the mouth of Ward Creek, 15 miles east of Silver Creek, the greenish argillites are about 1,700 feet thick. It is difficult to interpret the significance of this facies change because there is no time marker present. It is known that an argillaceous section overlain by banded argillites and limy quartzites and underlain by quartzites is relatively thin and typically purplish in Idaho, but is three times as thick and typically greenish in Montana. Several interpretations of the facies change are possible. First, the argillite may represent an equivalent time in Idaho and Montana, but with three times as great a thickness of argillite deposited in Montana as in Idaho, and under conditions of oxidation in Idaho and of reduction in Montana. The purplish color is produced by specularite, which contains ferric iron, and the greenish color is produced principally by chlorite, which contains ferrous iron, or perhaps by iron in other configurations. Because the St. Regis formation is typically quartzitic farther to the west near Pinehurst, Idaho, the suggestion of a gradation from nearshore facies in the west to offshore facies in the east might be a plausible interpretation. The thin purplish facies then might represent deltaic top-set beds which were subject to exposure and oxidation periodically, and the thick greenish facies might represent fore-set beds out of an oxidizing environment.

Such an interpretation cannot be certain, however, because other evidence suggests different correlations. For example, the quartzite beds below the argillite are much more impure in Montana than in Idaho, and south of the Osburn fault zone no white quartzites like those of the Revett quartzite were found. Thus the possibility exists that the Revett quartzite in Idaho grades eastward into a more argillaceous facies and parts of the rocks mapped as the St. Regis formation in Montana are the time equivalents of Revett rocks in Idaho. Likewise, greenish argillites are known in the Wallace formation in western Mineral County. Calkins (1908, p. 25) and Calkins and Jones (1914, p. 173) in reports on the Coeur d'Alene district included the greenish argillites at the top of the St. Regis in the Wallace formation; so at least part of the rocks mapped as St. Regis in Montana may be the time equivalent of Wallace rocks in Idaho. The St. Regis formation in Montana, as here mapped, may include the contiguous parts of the adjacent formations as they have been mapped in the Coeur d'Alene district in Idaho.

The predominance of argillite was used as the principal criterion in distinguishing the St. Regis formation, although quartzitic beds a foot or more thick can be found almost everywhere in the section. The contact between the St. Regis and the overlying Wallace formation is defined here as being at the top of the predominantly argillaceous series. Above the argillaceous series lies a section composed predominantly of alternate quartzite beds and argillite beds ranging from ½ inch to 6 inches in thickness, and accompanied almost everywhere by limy quartzite beds. At least two units of greenish argillite several tens of feet thick are included within the lowermost 1,000 feet of the Wallace formation above the contact as defined. The lower contact of the St. Regis formation has been placed where the predominantly argillaceous beds grade into the predominantly quartzitic Burke and Revett formations below. Of course, the boundaries between such units which intergrade are purely arbitrary.

All the preceding description of the St. Regis formation in Mineral County applies to the rocks south of the Osburn fault zone. North of the fault zone the St. Regis formation has the characteristics that it has in the Pottsville and Mullan quadrangles of Idaho. Exposures are extremely poor, however, and no continuous section is exposed. Isolated outcrops and float indicate that there is considerable purplish-gray argillite and thinly laminated green argillite. Purplish-gray argillites were found in two places between the north and south branches of the Osburn fault. This suggests a closer relation of these rocks to the rocks toward the north than to those toward the south. This relation in turn suggests that the major movement took place along the south branch of the Osburn fault.

In the Flat Rock syncline the St. Regis formation is predominantly greenish phyllite, with cleavage developed to a degree that obliterates bedding in many places. Exposures of the St. Regis are poor at the head of Twelvemile Creek but abundant float indicates a predominance of purplish-gray argillite with a relatively thin greenish zone at the top.

WALLACE FORMATION

The Wallace formation crops out over a large part of Mineral County, Mont. The formation has not been subdivided on the map, although four members are recognized in contiguous areas. The top of the Wallace formation was not found in this area; so, only a part of the formation is mapped.

The thickest section found is at the head of Savenac Creek near Mount Bushnell where about 6,500 feet of Wallace formation is exposed in the north flank of the Savenac syncline. Because the overturned Savenac syncline shows intense deformation, 6,500 feet may represent less than the original thickness. The base of this exposed section is a fault contact; nevertheless, the fault contact may be close to the true bottom of the section. The section can be divided approximately into the four units that follow:

	Feet
Argillite, thinly laminated, laminae commonly from paper thin to ¼ inch thick, contrasting dark- and light-gray; many limy beds	2,000±
Argillite, phyllitic, bedding obscure, light olive-gray	1,500±
Argillite, thinly bedded, dark-gray, relatively homogeneous	500±
Argillite and limy quartzite, banded and interbedded, bands commonly from 1 inch to 2 inches thick; limy parts etched on weathered surfaces and stained brown	2,500±
	6,500±

At the head of Flat Rock Creek the Wallace formation is composed principally of light olive-gray to brownish-gray phyllite. Some beds of crystalline limestone were found, and thinly bedded limy argillites and quartzites are common. In this area and in Twelvemile Creek valley the Wallace formation contains a myriad of small quartz lenses and veins. The veins are from one to several tens of feet long and are a fraction of an inch to a foot or more wide. They contain fragments of phyllite and some dark-green chlorite pods, but apparently no sulfides. The abundance of the quartz veins may in some way be related to the structural knot formed by the Flat Rock syncline crossing the Savenac syncline, but why the quartz is predominant in the Wallace and not in the other formations is not understood.

South of the Osburn fault the Wallace formation is well exposed in road cuts on the North Fork of Little Joe Creek and in cirques that head against the State-line divide, as at the head of Silver Creek, the Middle Fork of Big Creek, and Copper Gulch.

Exposures on Silver Creek suggest about 6,000 feet of Wallace formation, but unrecognized faults may have repeated the section. At the St. Lawrence mine, at the head of Silver Creek, the lithology is typical of the lower unit of the Wallace formation as known in the Coeur d'Alene district. The rocks consist of interbedded medium dark-gray (N4) argillite and light brownish-gray (5 YR 7/1) to yellowish-gray (5Y 7/1) limy quartzite. The beds of argillite and quartzite are most commonly 1 to 4 inches thick, and mudcracks are abundant.

The transition zone from the St. Regis formation to the Wallace formation is well shown on Silver Creek north of the mouth of Burke Creek and at the mouth of Dominion Creek. Like the boundaries between other formations of the Belt series, the boundary between the St. Regis and Wallace formations is not distinct. Units 10 to 50 feet thick of greenish-gray argillite typical of the St. Regis are separated from the main unit of St. Regis by 1,000 feet of interbedded argillites and quartzites typical of the Wallace.

GLACIAL DEPOSITS

Deposits of glacial and glaciofluvial origin mapped in this area are confined entirely to deposits formed by valley glaciers which occupied many of the larger valleys draining the north slopes of the major divides.

On the south side of the St. Regis River most of the tributaries which head against the State-line divide were occupied by glaciers for the upper third to upper half of their lengths, and cirques have been formed at the heads of each. The Middle Fork of Big Creek is typical; it has alluvium in its lower part, a canyon section of steep gradient in its middle part, a morain-covered broad valley in the upper part, and a cirque at its head. In similar tributary valleys east of Henderson the lower alluviated section is missing, for the St. Regis River itself in that area is actively cutting a canyon and has not reached grade.

The Middle Fork of Packer Creek is rather unusual. The headwaters are in a broad valley, and glacial gravels that cover the floor extend up the gentle northeast valley side to the divide between Packer and Wilkes Creeks. The head of Wilkes Creek is a cirque wall forming a rock step typical of glaciated valleys and very likely some of the drainage from Packer Creek flowed into Wilkes Creek at one time. Now, all the Packer Creek drainage flows southward through an ungraded section with many cascades and falls just below the broad headwater region to the St. Regis River.

LAKE MISSOULA DEPOSITS

Lacustrine silts, fluvial gravels, and ice-rafted cobbles and boulders are evidence that glacial Lake Missoula (Pardee, 1910, p. 376–386) flooded many of the valleys in the area mapped. These deposits are not differentiated on the map, for to do so would require a much more thorough study of their character and distribution than was possible during this reconnaissance of bedrock geology in the region.

Cobbles and boulders of red and purple quartzite from the Missoula group have been distributed, presumably by ice rafting, throughout the area mapped, although the nearest outcrop of similar rocks is near Superior, Mont., about 14 miles southeast of St. Regis. Such erratics have been found on Camels Hump Pass, at an altitude of 3,950 feet, near the northern branch of the Osburn fault on the Deborgia Cutoff Road at an altitude of 4,000 feet, and 1 mile southwest of Cabin City on a spur at an altitude of 3,950 feet. These points have the highest altitudes at which ice-rafted boulders were observed, and they indicate that the highest level of Lake Missoula was about 4,000 feet above sea level or perhaps slightly higher during at least part of its existence. The lake is known to have had a maximum altitude of 4,200 feet at Stevensville in the Bitteroot Valley (Campbell and others, 1915, p. 135); this corresponds closely to that suggested in the present area.

Three lines of evidence suggest that ice rafting has been the agency for distributing the erratics. First, isolated subrounded boulders of quartzite of the Missoula group as much as 2 feet in diameter are not uncommon on many hillsides otherwise covered with mantle from the underlying bedrock and with angular talus. At most such places there is no evidence of former terrace gravels of which the boulders might be remnants; their completely erratic occurrence is characteristic. Second, the distribution of these erratics can hardly be attributed to stream action because the possibility of former drainage from the Superior source area westward through St. Regis valley, Tamarack Creek valley, and many other tributaries seems ruled out by the general high elevation of the divide surrounding St. Regis valley. Drainage that could have flowed westward over these high divides would necessarily have been at a level of more than 1,000 feet above present drainage levels and could not have left erratics on the walls of valleys not yet developed. Third, there seems to be no supporting evidence of valley glaciers moving westward into St. Regis valley from the Superior area; thus, this means of transport is ruled out.

In a few places, especially at the head of Tamarack Creek and on West Twin Creek, quartzite erratics of the Missoula group are clustered in areas only a few acres in extent. Throughout the hummocky topography in the Osburn fault trough on Timber and Twin Creeks erratics were found on the crests of all hills traversed.

In addition to ice-rafted erratics, lacustrine silt deposits are widespread. One of the best exposures of silt is in Mullan Gulch from 1 to 3 miles west of St. Regis. Silt 20 feet thick is exposed in road cuts, and terraces are apparently cut in silt at a height of 50 to 75 feet above the valley bottom. The silt is light buff, occurs in flat-lying beds which are varved in some places, and contains abundant concretions having elliptical and irregular outlines. Many cuts in silt in Mullan Gulch and east of St. Regis on U. S. Highway 10 were searched for vertebrate fossils, but no bones or bone fragments were found. Silt beds believed to be lacustrine are abundant, although not thick throughout the topographic trough following the Osburn fault zone west of Henderson. The bedrock is obscured and only a few pieces of bedrock float have worked their way through the silt veneer although bedrock-type topography is readily recognized on aerial photographs. Partly because of this veneer, there is great uncertainty about bedrock identification in the fault trough area. A symbol has been employed on the map to indicate where the identity of the bedrock is especially uncertain. The symbol should not be construed to indicate distribution of Lake Missoula sediments, because undoubtedly other factors, principally the shattered character of bedrock in the fault trough, add to the difficulty.

DIORITE

Sills and dikes of dioritic composition make up a small proportion of the rocks of the region. The Wishards sill is the largest of these igneous bodies and crops out for a distance of more than 10 miles along the Montana-Idaho State line in the southwestern part of the area mapped. The sill is more than 400 feet thick in some places but is less than 50 feet thick in other places. Calkins and Jones (1914, p. 174) report that the Wishards sill persists from the head of Placer Creek southwestward to St. Joe River, 30 miles away. Wallace has seen some of these outcrops of the Wishards sill along the St. Joe River and on traverses has crossed outcrops of what may be a westward extension of the sill southwest of Stevens Peak in Idaho, between Stevens Peak and the Little North Fork of the St. Joe River.

Calkins and Jones (1914, p. 175) give a good general description of the rock as follows:

> The rock has the normal appearance of diabase. Its general color is black to dark gray with a tinge of green; its texture is coarse to fine. The minerals visible to the naked eye are white feldspar, dull greenish-black augite and amphibole, and black iron ore of metallic luster. The feldspar forms crystals that give many narrow oblong sections. No olivine is visible, even under the microscopic, which reveals considerable amounts of quartz, alkali feldspar, and biotite.

The diorite in places has a very high content of magnetite or ilmenite, in other places is nearly void of mafic minerals, and elsewhere has various amounts of magnetite, pyroxene, and amphibole.

The sill intrudes argillites and impure quartzites of the Wallace formation and the rocks both above and below the sill are metamorphosed. Metamorphism extends only a few feet from the sill and the argillites and impure quartzites have been changed to fine-grained, pale-gray hornfels.

Calkins and Jones (1914, p. 174–175) suggest that the Wishards sill was intruded before the Algonkian rocks were deformed and that it has been folded and faulted with them. In the paragraph describing the Crittenden Peak fault, the authors present evidence which, though uncertain, suggests that the Wishards sill may have succeeded a period of major faulting. This interpretation in turn suggests that the Wishards sill may have been intruded in Laramide or post-Laramide time.

STRUCTURAL GEOLOGY

GENERAL SETTING

The region has been subjected to intense folding and faulting. The major structural feature is the Osburn fault zone which approximately bisects the mapped region along a line trending N. 65°–70° W. All other major faults and fold axes roughly parallel this trend, although in gross pattern they trend slightly more north of west and appear to be truncated at a very low angle by the Osburn fault zone.

Deformation is much more intense in the structural block north of the Osburn fault zone than in the block to the south. On the north side of the fault zone overturned folds are the common structure, but on the south side overturning has occurred in only a few places. Most of the western half of the area south of the Osburn fault zone is underlain by a faulted homocline dipping south. The eastern half of the homocline is complicated by two eastward-plunging anticlines, and the north flank of each is truncated by a fault. South of the Osburn fault zone near the extreme western edge of the map are two overturned folds, and at the extreme eastern edge of the map the Wallace formation has been intricately folded. This alternation of intensely folded and relatively unfolded blocks south of the Osburn fault zone is typical of the area between Kellogg, Idaho, and St. Regis, Mont.

The Osburn fault zone itself is a complex of anastomosing faults, shears, and shattered zones ranging in composite width from 1,000 feet to 2 miles. A broad elongate topographic trough has been eroded in the soft broken rock along the general line of the Osburn fault zone. Pleistocene and Recent deposits occupy this trough and almost everywhere mask the fault zone, but gouge and intensely sheared rock are exposed in several places.

FAULTS

OSBURN FAULT ZONE

LOCATION

The Osburn fault zone has been traced continuously from Fernan Lake, near the city of Coeur d'Alene, Idaho, eastward through the Coeur d'Alene mining district to a point a few miles east of the Nancy Lee mine north of Superior, Mont. Its western extension is covered by Columbia River basalt (Anderson, 1940, pl. 2). A long-distance projection of its trend eastward suggests that a large fault zone a few miles north and northeast of Missoula, Mont., may possibly represent the Osburn fault zone. The length, therefore, is at least 90 miles and possibly more than 140 miles. The fault zone is marked throughout its entire length by such erosion features as deep saddles in ridges and structurally controlled valleys. Alluvium in valleys masks long sections of the fault zone, but the zone is well exposed in a few road cuts and river cutbanks and in several mine tunnels. To the west of the area studied, between the towns of Wallace and Mullan, Idaho, the fault zone can be seen in the Morning, Golconda, and Granada mine workings. Between Mullan, Idaho, and the Montana State line the fault zone lies under alluvium in the South Fork of the Coeur d'Alene Valley and crosses the Idaho-Montana State line through a saddle known as Mullan Pass.

Within the mapped area the fault zone lies about 2 to 3 miles north of the St. Regis River and is marked by a broad troughlike depression eroded in the crushed and sheared rocks of the fault zone. At Mullan Pass the fault zone seems to be more nearly one fault having a sheared and crushed zone several hundred feet wide. In contrast to this, to the east where the Osburn fault zone crosses Packer Creek, the fault zone is comprised of at least two distinct faults, one north and the other south of Meadow Mountain. In this western part of the area the fault zone crops out in several cuts along the Randolph Creek road, southeast of Silver Cable mine, and along one road cut southeast of Meadow Mountain. Its approximate position can be traced across Randolph Creek and along the West Fork of Packer Creek by a mantle composed principally of gouge and crushed quartzite. On aerial photographs, lineaments can be seen which coincide with these zones of gouge in the mantle and serve as corroborating evidence of the position of the fault zone.

Between Packer Creek and Twelvemile Creek the northern branch of the Osburn fault zone is clearly marked topographically by a south-facing escarpment that also appears as a prominent lineament on the aerial photographs. Intensely sheared rocks in this zone can be seen at the portal of the Saltese Consolidated mine. Near Twelvemile

Creek light-gray soil over the fault zone has proved by microscopic examination to be composed of fine-grained angular fragments, principally of quartz, evidently fault gouge. In this central segment of the Osburn fault zone most of the area south of the escarpment is obscured by Pleistocene(?) gravels, Lake Missoula sediments, and Quaternary alluvium, but the identification of several large faults suggests that more than two distinct faults here constitute the zone. Some of the southern faults seem to diverge from the main zone, as their eastern parts are farther from the main zone than their western parts.

East of Twelvemile Creek, near Camels Hump Pass, the northern branch of the Osburn fault zone appears to be the largest of several faults and was visible in a road cut at Camels Springs. In road cuts west of Camels Hump Pass, numerous intensely shattered zones were found. About 1½ miles to the south the Boyd Mountain fault may represent the southernmost element of the Osburn fault zone. However, a conspicuous saddle near Sloway Camp, a short distance east of the map area, suggests that a large fault zone diverges from the Osburn fault zone, and the Boyd Mountain fault may represent a western segment of the diverging fault zone. In prospect trenches on the Monarch vein at Shoemaker ranch, gouge zones indicate a large fault parallel to the Boyd Mountain fault.

An unusually sharp U-shaped meander of the Clark Fork River lies along the eastward projection of the Osburn fault zone north of St. Regis. Probably this meander is at least indirectly controlled by the fault zone.

DISPLACEMENT ON FAULT ZONE

Undoubtedly the Osburn fault zone represents an extensive structural break, but the amount and type of displacement are little known. If displacement of a fault is even crudely in proportion to its length and to the width of gouge and crushed zones, the movement on the Osburn fault must have been great, perhaps on the order of miles.

Apparent displacement is anomalous, for in the vicinity of Osburn, Idaho, the fault zone has brought rocks of the Prichard formation in contact with rocks of Wallace formation. This displacement indicates about 6,000 feet (Calkins, 1908, p. 62) of stratigraphic throw; yet east of Mullan, Idaho, and in the western end of Mineral County, Mont., rocks of the same formation are north and south of the fault. Thus, rocks of Wallace formation south of the fault zone are in contact with other Wallace rocks north of the fault zone and also the St. Regis formation is in contact with St. Regis rocks, and the Revett quartzite is in contact with Revett quartzite along the fault near the Idaho-Montana line. These relations might be explained in three ways: by differential vertical displacement, by strike-slip displacement cutting diagonally across structures deformed at an earlier time, or by a combination of both types of displacement.

Different structural arrangements are generally found on opposite sides of the fault, indicating that the fault is a major structural element. For example, in the Wallace-Mullan area northward-trending faults and folds are prevalent north of the Osburn fault and eastward-trending folds and faults are prevalent south of the fault zone. In western Mineral County structural trends are similar north and south of the fault zone, but folds are predominantly tight and overturned north of the fault zone in contrast to broad and open folds south of the zone. A reverse situation exists near Osburn, Idaho, where overturning is characteristic of the silver belt south of the Osburn fault zone, and open folds typify the northern block. A block of overturned folds also lies south of the fault just west of the Montana-Idaho State line. The mechanics for producing this structural discontinuity along the fault are difficult to conceive. One explanation may be that strike-slip of about 16 miles has offset earlier tightly folded blocks.

Near the mouths of Twelvemile and Flat Rock Creeks the Flat Rock syncline has been formed in the overturned flank of the Savenac syncline, and strikes of beds in the Flat Rock syncline are approximately parallel to a sharp bend in the north branch of the Osburn fault zone. These flexures in the sediments and the fault are interpreted as large drag features developed by strike-slip on the south branch of the Osburn fault zone when the south side moved westward at least half a mile. The cross-fold relationship of the Flat Rock syncline to the Savenac syncline, further discussed under "Cleavage, lineation, and minor structures," suggests a time relation in which overturned folds north of the fault zone were produced first and then a drag fold was produced in the overturned flank of an earlier overturned fold by strike-slip stresses along the fault zone. It might be postulated that the stress which produced strike-slip and the stress which produced overturned folds were merely parts of the same stress system, and that the Flat Rock syncline represents merely a late phase of strain. If this were true, however, the early folds should trend more nearly west or southwest, rather than parallel to the Osburn fault zone or more northwest than the Osburn fault zone as they do. The existing pattern is believed to indicate a fairly distinct separation in time of the strike-slip and overturned-fold phases of distortion. As will be indicated later in a discussion of faults which cut the Wishards sill, there may be a third and later phase of deformation which probably produced a relatively minor amount of displacement.

AGE OF FAULT ZONE

The age of the fault zone can be determined only within broad limits, and it seems possible that the general line of the fault zone has been in existence for a long period of time. The present shear zone, of course, can be no older than the Precambrian Belt series rocks which it cuts. At the other extreme, basalts of presumed Pliocene or younger age serve as a time marker. The basalts fill valleys incised in an old erosion surface, the Idaho peneplain. During the development of this peneplain all recognizable topographic expression of vertical displacement on the Osburn and related faults was removed. Thus major displacement must have taken place considerably earlier than the outflow of the basalts. Closer limits can be tentatively established by assuming a relation to other deformation in the Northern Rocky Mountains province, most of which took place in Late Cretaceous or early Tertiary time during what is generally called the Laramide revolution. The multiple deformation already suggested very likely was not confined to one simple period of deformation, but as yet no way has been found to determine dates of the different periods during which movement occurred.

Stratigraphic differences which have been recognized on opposite sides of the fault zone cannot yet be evaluated fully, but neither the possibility of large strike-slip displacement or primary differences in sedimentary environment can be ruled out as possible explanations. Primary differences in sedimentation across the line of the fault would be evidence that the fault was active during or before deposition of the Belt series. The Osburn fault may be one manifestation of an ancient deep-seated lineament which crosses the northern Rocky Mountains. The existence of a lineament of this sort even as early as the Precambrian is suggested by an eastward-projecting prong of the area of deposition of the Belt series rocks (Eardley, 1951, fig. 163, p. 287), and by a possible basement control of the localization of mineralized belts in the Wallace-Burke area of the Coeur d'Alene district.

TWELVEMILE FAULT

The upper part of Twelvemile Creek appears to follow a fault named the Twelvemile fault, and the divide between the heads of Twelvemile Creek and Knox Creek is a distinct saddle developed on the fault. The exact position of the fault is known with fair certainty only at the Twelvemile-Knox Creek saddle where float indicates a contact between the argillite of the St. Regis formation and the Revett quartzite. A structural discontinuity is suggested west of the saddle where beds of the Wallace formation appear to dip south beneath Revett quartzite.

The Twelvemile fault appears to be one of a group of faults forming a composite fault zone similar to but not of such magnitude as the Osburn fault zone. The Twelvemile fault may be the most important member of this fault zone. To the west, the shear zone projects approximately into the position of the Thompson Pass fault (Calkins, 1908, pl. 2), and further work may confirm that they are segments of the same structure.

From available data, displacement cannot be determined on the Twelvemile fault, although apparent displacement of the south side relatively upward is indicated. If this fault is the same as the Thompson Pass fault, strike-slip of several miles would be a probability. In the Thompson Pass area to the west, segments of the Granite Peak syncline are separated as much as 3 miles by the Thompson Pass fault (Calkins, 1908, pl. 2), and the southern segment is displaced westerly.

MOUNT BUSHNELL FAULT

In the vicinity of Mount Bushnell (north-central part of the map) the Revett quartzite is in contact with the Wallace formation even though all the beds have a general southward dip. The absence of the argillite of the St. Regis formation indicates a fault which has been named the Mount Bushnell fault. The exact line of the fault has not been identified in the field. Most of the St. Regis is absent from surface exposure along the strike of the beds for more than 3 miles; thus the fault appears to be almost parallel to the strike of the beds. South of Mount Bushnell about 1,000 feet, a few pieces of argillite float typical of the St. Regis suggest that at least some of the St. Regis formation is near the surface along the fault. Where the Deborgia Cutoff Road crosses the fault a small amount of float also suggests argillite of the St. Regis. The uppermost part of the section mapped as Burke and Revett formations also appears to represent beds which are transitional in character between Revett and St. Regis formations.

Lineaments that show on aerial photographs and the absence of strata in Twelvemile and Tamarack Creek valleys and in intervening areas are evidence of the eastward continuation of the Mount Bushnell fault, which is here called the Tamarack Creek fault. The net displacement on the fault is not known, but a stratigraphic throw of at least 1,000 feet is represented.

GOAT MOUNTAIN FAULT

Discontinuities of the stratigraphic section observed on the Deborgia Cutoff Road and on Savenac Creek suggest a large fault, but the position and trend are very poorly known, and it is possible that an entirely different interpretation may better explain the anomalies observed. The postulated fault is believed to pass a short distance north of Goat Mountain and is named after that point. Similar anomalies were found near Hawk Mountain and on Packer Creek, and the fault may be continuous to the west.

TAMARACK CREEK FAULT

Lineaments appearing on aerial photographs, which are interpreted as fault traces and which have been verified by field examination in a few places, suggest at least three major parallel faults forming a mile-wide band through Tamarack valley. The most clearly defined of these three is the Tamarack Creek fault. Although direct continuity has not been established, there is a suggestion that this group of faults represents eastward convergence of the Mount Bushnell and Goat Mountain faults with the Twelvemile fault.

A lineament has been traced eastward on aerial photographs beyond the limits of the map and may represent a continuation of this fault. At the Clark Fork River a zone of sheared rock several hundred feet wide is exposed where this lineament intersects road cuts near the mouth of Patrick Creek, about 1½ miles southwest of the Paradise Ferry over the Clark Fork River.

SILVER CREEK FAULT

A large fault extends from the upper part of the St. Regis valley southeastward for more than 15 miles. It was first recognized in the Silver Creek valley and thus is referred to as the Silver Creek fault. Westward from the mouth of Rainy Creek near the town of Taft, movement on the Silver Creek fault appears to have been dissipated in several minor faults. However, a fault of opposite displacement and slightly divergent trend continues westward beyond the edge of the map. On Ward Creek the quartzite of the Burke and Revett formations is faulted against phyllite of the Wallace formation and represents the easternmost point at which the Silver Creek fault is known with any certainty. From Ward Creek eastward the fault is obscure in a terrane composed entirely of Wallace rocks.

The Silver Creek fault can be seen as a body of sheared rocks more than 20 feet wide at the southern end of a railroad tunnel near Dominion Creek, and it is well marked by saddles and the structurally controlled drainage in the vicinity of Burke and Silver Creeks. The fault is known with fair certainty on the Middle Fork of Big Creek, on Deer Creek, and on Ward Creek; but on the East Fork and West Fork of Big Creek evidence of its existence and its position is obscure.

The southern side of the Silver Creek fault apparently has been upthrown about 2,000 feet in the vicinity of Silver Creek, and in the valley of the Middle Fork of Big Creek a stratigraphic throw of several thousand feet is indicated.

GILT EDGE FAULT

At the head of Gilt Edge Creek the Wishards sill is offset about 250 feet by a fault which shows distinctly as a lineament on aerial photographs. This fault is called the Gilt Edge fault. To the east, in other tributaries of Big Creek and in Deer Creek, repeated stratigraphic sections suggest that the Gilt Edge fault continues its known trend eastward for 7 miles and may join the Silver Creek fault near Deer Creek. A greater stratigraphic throw is indicated in the Middle Fork of Big Creek than where the fault cuts the Wishards sill. To the west the Gilt Edge fault appears to pass through the Stewart prospect south of the Monitor mine.

CRITTENDEN PEAK FAULT

A fault which cuts the Wishards sill near Crittenden Peak and which shows on aerial photographs as a definite lineament is called the Crittenden Peak fault. The Crittenden Peak fault strikes about N. 70°–80° W. and may be continuous with the fault that is accompanied by a sharp flexure at the Deer Creek mine. There is little evidence of the fault at the place it would presumably cross the Middle and East Forks of Big Creek. Float found in the Middle Fork suggests that argillite of the Wallace formation is in contact with quartzite of the Burke and Revett formations and also suggests the presence of a fault. In addition, an extrapolation of trends of bedding from localities where evidence is clearer produces a structural pattern consistent with the interpretation of a fault. In the East Fork no stratigraphic break was identified. In both the East and West Forks glacial gravels in the valleys made reconnaissance traverses rather unproductive of evidence.

The direction of relative displacement of bedding in the Middle Fork of Big Creek is interpreted as being opposite from that of the offset of the Wishards sill; however, there is considerable uncertainty in the interpretation of the stratigraphic relations in the Middle Fork of Big Creek. If the interpretation is correct, a twofold history of movement on the fault is indicated, and a possible post-Precambrian age of the Wishards sill is strongly suggested. Furthermore, the largest movement would have preceded intrusion of the Wishards sill. If the major faulting is Laramide, the Wishards sill must be at least that young.

PLACER CREEK FAULT

The Placer Creek fault is well known in Idaho where many prospects have been developed along it, and topographic features such as saddles and controlled drainage mark its position. The eastern end of this fault is shown in the western part of the area mapped. Its eastward extension has been recognized entirely by lineaments seen on aerial photographs. It is possible that the Placer Creek fault converges with the Silver Creek fault.

THE HOPE AND UNNAMED FAULTS

The Hope fault may cross the northeastern corner of the map, but it was not identified in the mapped area. It may, however, follow approximately the valley of Cherry Creek.

Many faults shown on the map were not named because some are relatively small, others are postulated on weak evidence, and little is known about still others.

Near Wards Peak is a group of faults, some of which are exceptionally well exposed in the cirques at the heads of Newman, Ward, and Deer Creeks. Particularly at the head of Newman Creek, where large dip slopes are bared by glacial erosion, the massive beds of quartzite of the Burke and Revett formations can be seen to be sharply flexed and broken. Diabase dikes appear to follow some of these faults on the southeast flank of Wards Peak and at the Aladdin mine.

About 2 miles upstream from the mouth of Twomile Creek wide sheared zones are exposed in road cuts, and lineaments on aerial photographs delineate three faults completely within the Wallace formation. None of these faults could be traced for any great distance.

A few hundred feet east of the mouth of Savenac Creek a fault surface is exposed; the fault zone, now silicified and stained with a small amount of limonite, stands out in brown faceted spurs. The quartzites of the Burke and Revett formations near the fault are shattered and bleached.

One-half mile east of the fault exposure at the mouth of Savenac Creek another body of intensely distorted and faulted rocks is exposed in a road cut on the main highway. Although these two fault zones probably are not the same fault, the two together do show the presence of a disturbed zone which seems to trend more southeasterly than the Osburn fault zone, as though diverging from it.

In Twelvemile Creek small faults are shown associated with the Flat Rock syncline. Although these are very poorly defined, it is obvious that there is faulting in this highly strained block of rocks. Only detailed mapping and study will delimit the complex structure exactly.

Near the junction of the East and West Forks of Big Creek two road cuts expose wide zones of sheared rocks. The southernmost exposure appears to represent a fault with a northerly strike and a relatively shallow dip to the east. The strike and dip, if interpreted correctly, represent an unusual trend in the area mapped. The northernmost exposure is thought to be part of the same fault, but it may strike northwesterly and be related to fault zones exposed in road cuts along U. S. Highway 10 east of Saltese.

FOLDS

SAVENAC SYNCLINE

Between the Twelvemile fault and the Goat Mountain fault rocks of the Burke and Revett formations, the St. Regis formation, and the Wallace formation are involved in a large, tight syncline, which appears to control the trellis-type drainage net of the headwaters of Savenac Creek. The syncline is named the Savenac syncline after this locality.

The Savenac syncline apparently extends from the north-central part of the map for at least 12 miles southeastward to the vicinity of Flat Rock Creek. The axis has not been accurately identified along any part of it although foliated rocks near the axis are believed to control the drainage of the headwaters of Savenac Creek, and near the DeBorgia Cutoff Road observed outcrops give fair evidence of the position of the axis. In the northwestern part the fold is nearly isoclinal, with flanks dipping 70° to 90°. In the southeastern part the fold not only is essentially isoclinal but is also overturned, so that the axial plane dips about 55° to the south.

FLAT ROCK SYNCLINE

A sharp flexure has been produced in the southern overturned limb of the Savenac syncline near Flat Rock Lookout and is referred to as the Flat Rock syncline (see fig. 74). The Flat Rock syncline is referred to as a "syncline" although by some definitions it might be considered an overturned anticline. As the fold is thought to have been produced by a downwarp in previously overturned beds, and as it now is made up of beds which dip toward each other, it seems preferable to use the designation "syncline." Although small compared to the Savenac syncline, the Flat Rock syncline is important because it provides one of the few pieces of evidence suggesting that the movement on the Osburn fault zone was in large part horizontal and that the north side moved relatively eastward. (In the paragraphs on the displacement on the Osburn fault the significance of the Flat Rock syncline is considered in more detail.) The fold

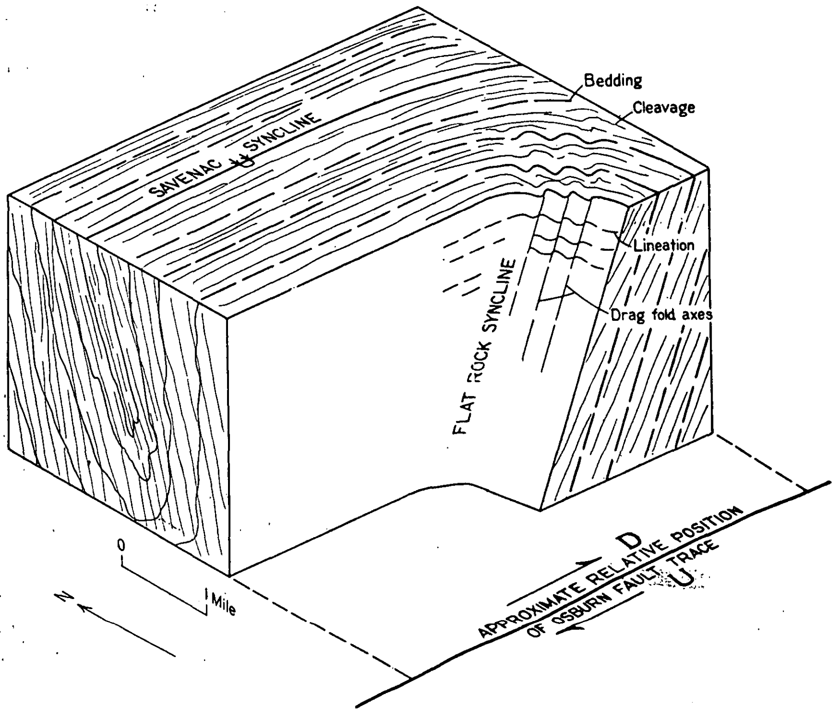

FIGURE 74.—Block diagram of the Savenac and Flat Rock synclines.

involves rocks underlying about 10 square miles of the mapped area. Its axis plunges about 35° to the southwest, and the two flanks form an angle slightly less than 90° with each other.

BOYD MOUNTAIN ANTICLINE

From Haugan eastward the St. Regis River approximately follows the axis of an anticline which is best exposed on Boyd Mountain and which is called the Boyd Mountain anticline. Although attitudes of bedding in the vicinity of Boyd Mountain indicate the anticline, and the axis is drawn on the map only in this locality, the pattern of outcrop of stratigraphic units shows more clearly the gross nature and trend of the fold. From this pattern it appears that the Boyd Mountain anticline is truncated at a very low angle by the Osburn fault zone. The Boyd Mountain anticline may possibly be correlated with the Lookout anticline, in which case the north flank of the fold has been sliced off by the Osburn fault in the vicinity of Mullan Pass.

The Boyd Mountain anticline has minor flexures, particularly near its axis, and it is also complicated by associated faults. The south flank of the Boyd Mountain anticline dips at angles generally between 20° and 50°, but the attitude of the north flank is poorly known except near Boyd Mountain beacon where the beds are near the Osburn fault zone and are overturned, having dips as low locally as 10°.

EAGLE PEAK ANTICLINE

The axis of the Eagle Peak anticline is a few hundred feet north of Eagle Peak. This anticline is the largest of several folds exposed in the cirques at the heads of Newman, Ward, and Deer Creeks. As the pattern of outcrop of stratigraphic units shows, the anticline plunges southeastward, but its eastward extension was not traced beyond the Aladdin mine. To the west the anticline disappears in a homocline dipping generally southward, and the north flank is truncated by the Silver Creek fault.

LOOKOUT SYNCLINE AND LOOKOUT ANTICLINE

The axis of the Lookout syncline is about half a mile south of Lookout Pass and has an easterly trend. It is known as far as 2 miles west and 3 miles east of Lookout Pass. The syncline is almost parallel to the Lookout anticline, an anticline overturned to the north, the axis of which is about a mile north of the axis of the Lookout syncline.

To the east both of these folds die out in the homoclinal structure which underlies much of the area mapped south of the Osburn fault zone.

SWAMP CREEK ANTICLINE

In the northeastern corner of the area mapped, in Swamp Creek valley, an overturned stratigraphic section was found in which parts of all formations from Prichard through Wallace are present. Near the Miller mine, at the head of Swamp Creek, a thin stratigraphic section of argillites of the Prichard formation which is not overturned was identified, and it is believed the axis of a major anticline is represented by the flexure thus defined. The anticline is referred to as the Swamp Creek anticline. The axial plane dips steeply to the south, and the axis trends northwestward. A large anticline east of Thompson Falls is believed to be this same fold, but there, although asymmetrical, it is not overturned as on Swamp Creek. If the Thompson Falls anticline correlates with the Swamp Creek anticline, the structure must be more than 15 miles long. The fold in Swamp Creek may be overturned because of its nearness to the Hope fault, which may pass through the area.

CLEAVAGE, LINEATION, AND MINOR STRUCTURES

Two kinds of cleavage are recognized. One is related to folding and is termed "axial-plane cleavage" because it tends to subparallel the axial planes of the folds. The second type seems to be related to faulting. Axial-plane cleavage is useful in the identification of overturned beds, but care had to be exercised not to confuse cleavage related to faulting with axial-plane cleavage.

Cleavage most commonly ranges in strike between N. 45° W. and N. 70° W. and in most places has a steep dip to the southwest. Well-developed axial-plane cleavage nearly parallels bedding in the isoclinal Savenac syncline, and in many places where phyllites have been produced bedding is obliterated. Phyllitic axial-plane cleavage, related to the Savenac syncline, has been warped around the axial plane of the Flat Rock syncline just as bedding has been warped. At the axis of the Flat Rock syncline, for example, phyllitic cleavage is at right angles to the axial plane, and on the southeast flank cleavage strikes northeast and dips northwest. This relationship strongly suggests that the Flat Rock syncline is a crossfold produced after the Savenac syncline and cleavage related to the Savenac syncline had been formed. The Flat Rock syncline, therefore, appears to be good evidence of a period of deformation distinctly later than the period in which the overturned Savenac syncline was produced. As described in the discussion of the Osburn fault zone, this late period of deformation appears related to that fault zone. The Flat Rock syncline is believed to represent a large drag fold indicating a large horizontal component of net slip on the Osburn fault zone.

Lineation is present in many places, especially in bodies of phyllitic rocks, and appears as small ridges and troughs on the planes of folia and as streaks of mineral grains. Lineation of this same type, studied more carefully in the Pottsville quadrangle, Idaho, by Wallace, is believed to be parallel to the orientation of shearing movement. In the Pottsville quadrangle the lineation generally plunges down dip, or steeply to the west; but examples were found in Mineral County where lineation plunges to the west at angles as low as 20°. Thus, in Mineral County, this type of lineation suggests more of a strike-slip component of shearing, at least locally, than is suggested by lineation in the Pottsville quadrangle to the west.

"Puckers" is a term coined to refer to secondary shear zones crossing foliated rocks in which the folia have not been ruptured but merely bent sharply to form Z-like flexures. "Fracture cleavage" is used by some to refer to similar structures, which are much smaller or, even microscopic. The axes of these small folds generally are nearly horizontal in Mineral County, as in the Pottsville quadrangle, and the planes of the shear zones dip at low angles either to the north or south. The fold axes of puckers produce a second type of lineation conspicuous on cleavage planes. In the Pottsville quadrangle it was found that the lineations believed to be parallel to shearing movements generally are at right angles to the pucker-fold axes. The two types of lineation, therefore, were interpreted as resulting from the same movement within the phyllitic bodies; namely, a near dip-slip orientation of shearing. In Mineral County the same relationship is generally true, but pucker axes were found which plunge 35° east, whereas shear lineations in the same outcrop plunge 25° west.

If there has been a large strike-slip component on the Osburn fault zone, a shear component of steep dip as suggested by steep lineation and nearly horizontal puckers is anomalous. The shear component of steep dip possibly represents a period of deformation distinct from that represented by strike slip on the Osburn fault zone, but its place in the tectonic history is not understood.

Foliation, lineation, and puckers are all produced in areas of intense deformation, and are, therefore, much more common north of the Osburn fault zone than south of it.

Minor folding is far more common in the Wallace formation than in the other formations. This characteristic is especially well shown along the North Fork of Little Joe Creek. Flexures in even the most competent quartzites in the stratigraphic section, however, are common and attest to the relatively plastic behavior of the rocks of Belt series under proper conditions.

ALTERATION

So-called "bleaching" in the Coeur d'Alene mining district has been used as a guide to ore deposits, and it is considered by some to be related, at least indirectly, to the solutions which introduced the ore minerals. Mitcham (1952) has presented an excellent review of the ideas concerning "bleaching." The term "bleaching" refers to the change in color of the sediments, usually from darker to lighter shades, presumably by hydrothermal alteration. Sericitization, silification, pyritization, carbonatization, and chloritization are the principal types of alteration involved.

In Mineral County "bleaching" is not as widespread as in the Coeur d'Alene district. Hydrothermal alteration, or "bleaching," appears to be localized along major faults, but it pervades some of the unsheared country rock, principally in a belt approximately a mile wide along the north side of the Osburn fault zone. In the Osburn fault zone itself rocks are intensely bleached and altered, although hydrothermal alteration is difficult to identify with certainty where rocks are sheared and gougelike.

The green color of the upper part of the St. Regis formation in Idaho has been considered by some to represent the introduction of material by one phase of hydrothermal alteration, but it is considered by the authors to represent either alteration of material in place or possibly an original characteristic of the sediments. The pale-green chlorite, which is responsible for the color, appears to have a particular affinity for argillite beds which are typically thinly laminated. In many places discrete units of the thinly laminated argillite are green, whereas the adjacent beds of other lithologic character are not green and are not bleached. Such a correlation of the chlorite with lithology suggests that an original compositional difference is responsible for the chlorite, and that it has not been introduced by hydrothermal solutions. Further evidence that the chlorite is related to a factor of sedimentation rather than hydrothermal alteration is that in Mineral County, where the St. Regis formation is more than twice as thick as in Idaho, chlorite imparts a greenish-gray color to the formation. Pale-green chlorite is not confined entirely to the St. Regis formation but is found in almost all the other formations also. In the Wallace formation light olive-gray (5Y 6/1) colors can result from the presence of chlorite plus other pigment material. Other greenish hues of gray (5Y 6/1, 5 GY 6/1) which are so common in the Belt series rocks probably result in part from the presence of chlorite in the sediments. Some highly sericitic rocks are a hue of greenish gray, but they generally are a more yellowish hue. The pale-green chlorite as it now exists may or may not be an original constituent of the sediment even though the chlorite may have been derived from original constituents rather than from introduced material. There has been at least some recrystallization during which chlorite has enlarged locally to grains a millimeter or more in diameter.

Besides hydrothermal alteration, dynamic metamorphism has played an important role in Mineral County. North of the Osburn fault zone, where the beds have been tightly folded, many of the argillites have been changed to phyllites and schists, and bedding in a great many places has been obliterated. All the quartzites examined microscopically are metaquartzites having grain boundaries at least partially sutured.

MINERAL DEPOSITS

GENERAL FEATURES

In western Mineral County certain mineral deposits are very distinctly related to prominent structural features and other deposits are somewhat less distinctly related to basic igneous rocks. The Osburn fault zone seems to be one of the major control structures; the Silver Creek fault and associated fractures also appear to have been the locus for ore deposition, and many small veins are known to be associated with other fractures in the region. In addition, several deposits are localized in or near the Wishards sill and other diorite sills and dikes.

DEPOSITS NEAR THE OSBURN FAULT ZONE

The belt of deposits near the Osburn fault zone include the following mines and prospects from west to east: Silver Cable, Bryan, Last

Chance-Ben Hur, Hemlock, Galligar, Tarbox, Wabash, Meadow Mountain, Black Traveler, Saltese Consolidated, East Coeur d'Alene, Copper Rock, True Fissure, Monarch, Wolf, and Keith. The Rock Island, Valentine, and Texas properties might be included in this group except that they are about 2 miles north of the Osburn fault zone and perhaps represent a different structural setting.

The veins near the Osburn fault zone are similar to the veins of the Coeur d'Alene district; in fact, this mineralized belt can be considered a continuation of the belt in Idaho near the Osburn fault, which contains such mines and prospects as the Golconda, Alice, Lucky Friday, Vindicator, and Idaho Silver. Near the Osburn fault zone in Montana galena is the most common ore mineral, and sphalerite is abundant in some properties. Silver-rich tetrahedrite and chalcopyrite are relatively more common than in the Idaho deposits. Ankerite and quartz are the common gangue minerals; but massive barite is abundant in at least two veins, the Monarch and a prospect just north of the West Fork of Packer Creek. All the veins are of fissure type, filling cavities along fractures in part and replacing the wall rock in part. Most of the veins trend west or north of west and dip 45° or more to the south. However, the Silver Cable vein strikes northeast and dips southeast, and the True Fissure vein strikes north and dips west. In general, the ore shoots are shorter in strike length than in dip length, and most are not more than a few tens of feet long. A westward rake of these elongated ore shoots appears to be common.

The following descriptions are of the mines that were accessible to the authors.

SILVER CABLE MINE

The Silver Cable mine is near the head of Brimstone Creek about 4½ miles north of Taft, Mont. The workings consist of three levels, of which only the lower level was completely accessible and the upper level partly accessible (pl. 49). The first 200 feet of the lower level exposes thick-bedded white Revett quartzite. A fault separates this quartzite from the light greenish-gray, impure, altered quartzites and argillites of the Burke formation which are exposed in the remaining workings of the lower level and in the upper accessible level. The beds strike approximately east and dip from 45° south to 50° north, with the north dips being overturned.

The vein, exposed in the lower level of the Silver Cable mine, strikes approximately N. 45° E. and dips 35° to 40° to the southeast. The vein is composed of tetrahedrite, galena, sphalerite, chalcopyrite, and a little pyrite and has a quartz and siderite gangue. According to Calkins and Jones (1914, p. 20), before the lower tunnel was driven, the best showing of ore minerals was in the upper level where the vein reportedly was about 4 feet thick. Unfortunately the vein on the upper level was not accessible to the authors, but the stope above the lower level has about the same width. No data were available on the past production of the Silver Cable mine.

LAST CHANCE MINE

The Last Chance mine, (pl. 50), owned by the Day Mines, Incorporated, is 3½ miles north of Saltese, Mont., on a tributary of the West Fork of Packer Creek. The workings consist of seven levels and the 2,000 foot caved Ben Hur tunnel; however, only three levels (No. 1 or U. S. Tunnel, and Nos. 3 and 6) were partly accessible. In the U. S. Tunnel (No. 1 level) which is the lowest of the three and the most recently worked, the Revett quartzite, consisting of white quartzite with an occasional bed of greenish-gray argillite, is exposed for 1,300 feet. Greenish-gray argillite, which probably belongs to the Wallace formation, is exposed in fault contact with the Revett quartzite near the caved portion of the U. S. Tunnel. The beds strike east and dip 85° south to 50° north, with the north dip probably overturned.

The Last Chance vein, where exposed in the U. S. Tunnel, is a pod along the fault between the Revett quartzite and the Wallace formation. The fault strikes northeast and dips 65° south. The vein consists of tetrahedrite, chalcopyrite, and some galena in a gangue of quartz and siderite.

The following table gives figures from company records indicating the amount and kind of ore in 4 shipments, 1 in 1940, 2 in 1943, and 1 in 1951:

Year	*Amount produced (tons)*	*Gold (ounces per ton)*	*Silver (ounces per ton)*	*Lead (percent)*	*Zinc (percent)*	*Copper (percent)*
1940	33. 63	0. 10	102. 5	1. 2	0. 3	-------
1943	19. 25	------	31. 6	. 2	. 3	0. 98
1943	2. 63	. 018	19. 4	12. 65	. 4	-------
1951	256. 00	------	2. 4	2. 7	. 4	-------

The Ben Hur tunnel was completely caved at the portal when the authors visited the property in 1952. The 2,000-foot Ben Hur tunnel was driven to tap the two veins which, according to old company reports, strike east and dip toward each other on the No. 2 and No. 3 levels (pl. 50). Although the veins were probably intersected, there is no record that they were mined at this lower level.

WABASH, MEADOW MOUNTAIN, AND TARBOX MINES

The Wabash, Meadow Mountain, and Tarbox mines are owned by the Mineral King Mining Company of Missoula, Mont. These mines are about 3 miles north of Saltese, Mont. on the Middle Fork of Packer Creek.

The Wabash mine consists of one tunnel which bears N. 55° E. and which was completely caved 150 feet from the portal. The tunnel exposes altered and crumpled argillites and quartzites of the Wallace formation, which dips moderately southwest. Unfortunately, no information is available about the composition, position, or extent of the Wabash vein.

Two levels of the Meadow Mountain mine were partly accessible. The No. 2 level was driven N. 30° E., but it was caved 150 feet from the portal. The No. 1 level, about 125 feet above the No. 2 level, has a bearing of N. 40° E. and is caved at 140 feet. About 120 feet from the portal a 60-foot drift was driven in a S. 70° E. direction. The vein, exposed in a small stope at the junction of the drift and the adit, consists of 5 to 10 inches of galena in a quartz and siderite gangue. The vertical vein is along a bedding-plane fault zone of crushed and crumpled argillites and quartzites (Wallace formation) striking N. 75° W. According to Calkins and Jones (1914, p. 194), the Meadow Mountain mine workings intersected two veins. The south vein contained considerable pyrite and the north vein contained appreciable amounts of galena.

The Tarbox mine (fig. 75) comprises an 800-foot shaft which collars near creek level and various levels of workings totaling nearly 4,300 feet. The lowest level is 1,000 feet below the collar of the shaft. The workings were caved and flooded and thus inaccessible to the authors. According to old company reports, no ore has been produced from this mine, which was allowed to fill with water in December, 1922. The vein material on the dump includes siderite, quartz, galena, pyrite, and limonite.

ROCK ISLAND MINE

The Rock Island mine (pl. 50) is near the head of Rock Creek about 4½ miles northeast of DeBorgia, Mont. The workings consist of three levels and a 90-foot raise connecting the upper two levels. The lower level, however, was inaccessible. Interbedded thinly laminated dark-gray argillites and limy brownish-gray quartzites of the Wallace formation are exposed at this mine. The beds strike northwest and are overturned, with dips ranging between 40° to 60° to the south.

The Rock Island vein strikes approximately east and dips 30° to 40° to the south. A shootlike vein, about 50 feet in strike length and at least 160 feet in dip length, is exposed in the raise between the middle and upper levels. The vein consists of irregular pods of quartz and sulfides along a fault zone. Galena, chalcopyrite, pyrite, and pyrrhotite make up the sulfides of the vein. The principal secondary minerals are cerussite, malachite, azurite, chrysocolla, and limonite. Reportedly, 1 or 2 car loads of low-grade ore have been shipped from the Rock Island mine.

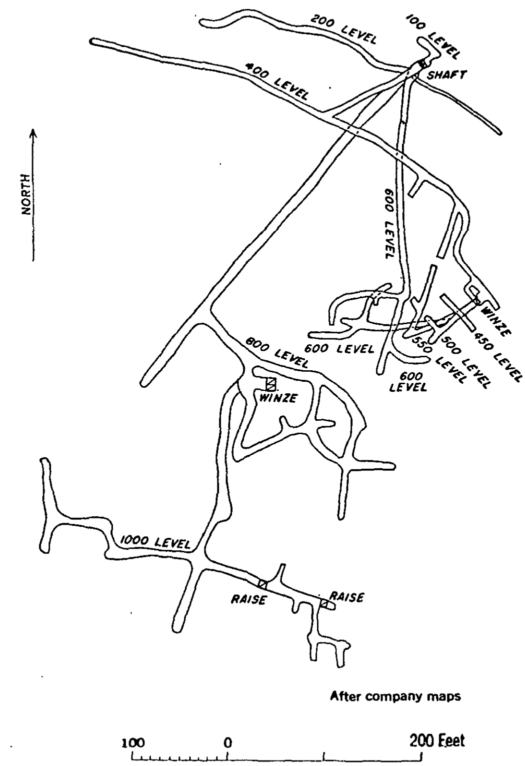

FIGURE 75.—Map of underground workings of the Tarbox mine.

TRUE FISSURE MINE

The True Fissure mine is about 2¾ miles northeast of DeBorgia on East Twin Creek. The accompanying map (pl. 51) is after one prepared by Garth Crosby of Day Mines, Incorporated, of Wallace, Idaho. The mine is in quartzites of the Burke and Revette formations one-half mile north of the Osburn fault zone. The quartzites of this block immediately north of the Osburn fault are greatly deformed and are in tight, overturned, nearly isoclinal folds. In one relatively large drag fold, beds have been rotated more than 180°. Vein material exposed in both adits consists chiefly of siderite, hematite, quartz, and pyrite, with some galena and a little chalcopyrite. Samples taken from the lower adit are reported to contain 1 to 3 ounces of silver per ton and 5 to 10 percent of lead per ton. Of particular interest is the northerly strike of the vein, which is unlike that of most other vein trends in the region. The relative positions of the veins exposed in the upper and lower adits, if they represent parts of the same vein, indicate a plunge of the long axis of the vein of approximately 45° to the southwest.

DEPOSITS NEAR THE WISHARDS SILL

The deposits in the vicinity of the Wishards sill, an intrusive mass of dioritic composition, are typically chalcopyrite-dolomite veins filling steeply dipping eastward-trending fractures. These include the Monitor, Stewart, St. Lawrence, Richmond, and Hansy deposits which occupy fractures from a few hundred to a thousand feet vertically above the Wishards sill. The Bullion vein and other veins farther west in Idaho occupy fractures related to the Placer Creek fault. Although the Bullion vein and other related veins are not in positions above the Wishards sill, they are generally no more than 1,000 feet away from it.

The spatial relation of these copper veins to the dioritic rocks is rather striking. However, the present study has produced no other specific evidence to suggest a direct genetic connection between the copper-bearing veins and the dioritic rocks. Furthermore, there are several significant copper deposits, including the Snowstorm and the Copper King, in the area directly east of Mullan, Idaho. These copper deposits are on the opposite side of the Osburn fault from the Wishards sill and have no apparent proximity to any intrusive rocks. Much more detailed work will be necessary to establish the relation of the predominantly copper-bearing veins to the predominantly lead-zinc-silver veins and to establish the relation of both types of veins to an ultimate source.

At the head of Gilt Edge Creek one massive dolomite vein was found occupying a position along the Gilt Edge fault where diorite is on the south and the Wallace formation is on the north. The Buffalo vein is reported to contain galena, chalcopyrite, and a few pods of free gold; but this property was not visited.

ST. LAWRENCE MINE

The St. Lawrence mine is south of and above Silver Lake, which is drained by Silver Creek. The mine is about 4½ miles south of Saltese, Mont. The workings consist of two partly accessible levels (pl. 50). The mine exposes gently dipping interbedded, medium dark-gray argillites and light brownish-gray to yellowish-gray limy quartzites of the Wallace formation. The vein occurs as pods along vertical fractures trending N. 70° E. and is composed of chalcopyrite in a dolomite and quartz gangue. Several raises and stopes have been made, but there is no record of the past production.

DEPOSITS NEAR THE SILVER CREEK FAULT

Deposits of chalcopyrite, quartz, and some galena are along the Silver Creek fault and its branches.

The Silver Strand property, near the St. Regis River and about 2 miles west of the mouth of Randolph Creek, was examined, although only a short section of one tunnel was accessible. Chalcopyrite was the principal mineral exposed but some malachite and azurite were also found; some galena is reported to be present.

The Agnes property, 2½ miles southwest of Saltese, was not visited. It is reported to contain copper and lead minerals, principally chalcopyrite and various products of oxidation, and galena.

The Silver Creek fault may be continuous with faults in the Atlas property near Mullan, Idaho, where 20-foot wide veins of ankerite containing chalcopyrite and some galena are known.

The workings of the Amazon Dixie mine, which is about 1 mile south of Lookout Pass on the south side of the St. Regis River, were inaccessible. Ankerite vein material was found in Copper Gulch on the dump of the upper workings of the mine, but the exact position of the vein could not be determined.

OTHER DEPOSITS

At the Miller property at the head of Swamp Creek and at the Silver Bell property on the North Fork of Little Joe Creek, quartz veins in diorite dikes have been prospected. In both prospects quartz is by far the most abundant mineral, and pods of galena, chalcopyrite, and sphalerite in the quartz are relatively rare. The Silver Bell veins appear to occupy tension cracks in the diorite dike. There are many similar veins in other diorite bodies in northern Idaho and western Montana, but none has produced a large amount of ore.

The Deer Creek vein near Crystal Lake, 5 miles southwest of Deborgia, Mont., was prospected and worked for its gold content as was the Aladdin vein, 9 miles southwest of St. Regis, Mont. It is reported that neither has produced much gold. The Aladdin mine and a prospect half a mile southeast of Wards Peak are on veins occupying shears in or adjacent to diorite. The veins are principally quartz but contain a little chalcopyrite and pyrite.

Most of the creeks have been prospected for placer gold, and placer ground on Deer Creek has been patented. Placer mining, principally by hand, was done on Deer Creek and Big Creek, and it is reported that although total production was not great some rich areas were found. Large piles of hand-sorted boulders in Deer Creek show what difficulties must have been encountered.

SUGGESTIONS FOR PROSPECTING

By far the most promising area for exploration is the mineralized belt following the Osburn fault, where it is already known that many veins do exist. Vegetation and a thick mantle obscure most of the bedrock and very possibly cover some unknown veins, but bulldozer trenching and diamond drilling can be used effectively to outline known veins more clearly and to reveal new veins. The area appears to be well suited to geochemical prospecting (Kennedy, 1952) and this method well may be used to find targets suitable for detailed physical exploration. Although no large ore bodies have been found in this belt along the Osburn fault zone, the similarity of structure and mineralogy to the structure and mineralogy of the Silver Belt of the Coeur d'Alene district and the general continuity of structure with that of the Golconda-Lucky Friday belt in Idaho suggest that exploration in this belt is warranted. Unless new methods of prospecing are developed, deep workings may be necessary to test adequately the potentialities of this block of ground.

The Silver Creek fault may be an important ore-bearing structure. It is one of the largest faults in the area and is known to have a few scattered mineral deposits along and near it. Geochemical prospecting near the base of valley walls where they are crossed by the Silver Creek fault should provide a relatively inexpensive method of exploring the fault zone for significant mineralized bodies.

In the Tamarack Creek valley and in the head of the Flat Rock Creek valley there is an area underlain by intensely faulted and deformed rocks. In the Coeur d'Alene district of Idaho structural knots are thought to be favorable for the deposition of ore if ore-bearing solutions are present. Although no sulfides are known to have been found in this area, the area warrants attention.

It is likely that other veins similar to the Hansy and St. Lawrence can be found near the Wishards sill. Aerial photographs show clearly the line of fracture the St. Lawrence vein follows and also the fractures other minor veins on the property follow. Many similar fractures, which very possibly contain copper minerals, can also be identified on the aerial photographs. For example, the Crittenden Peak and Gilt Edge faults show clearly on the photographs and may warrant prospecting, especially west of the outcrop of the Wishards sill. The Hansy and St. Lawrence veins probably are the sort of veins that might be expected along these fractures.

It is also likely that other veins similar to the Miller and Silver Bell can be found by prospecting areas underlain by diorite sills and dikes; but under present economic conditions, it will be a rare one that contains workable metalliferous deposits.

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