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GEOLOGY AND ORE DEPOSITS
OF THE CLARK FORK DISTRICT, IDAHO

by

ALFRED L. ANDERSON

UNIVERSITY OF IDAHO
MOSCOW, IDAHO
Entered as second class matter August 11, 1924, at the postoffice at Moscow, Idaho
under the Act of March 3, 1879
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GEOLOGY AND ORE DEPOSITS
OF THE CLARK FORK DISTRICT, IDAHO

By ALFRED L. ANDERSON

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The investigation represented by the present report was undertaken by the Idaho Bureau of Mines and Geology when the discovery of rich lead-silver ore in 1926 attracted wide attention to this little known mining district. As only a very small part of the area had been covered in geologic surveys, little or nothing was known of the geology of most of the region and nothing of the mineral deposits. It was, therefore, necessary to make a reconnaissance study of the general geology of the region, as well as the detailed examination of the ore deposits. As much of the area is described for the first time, more space is devoted to the general geologic features than is ordinarily given in a purely economic report so that the information, most of which is essential to a proper understanding of the mineralization, might also be available to those who contemplate further study in the district. Several problems of purely scientific interest were encountered in these studies, but these are reserved for more appropriate publications and have been given only incidental treatment in this report. In studying the ore deposits, particular attention was given to the genesis of the deposits and the relation of the deposits to structural features so that an adequate basis might be offered for intelligent exploration.

The outstanding economic feature is the presence of small rich deposits of lead-silver ore that can be worked with comparatively little capital. Other features are the large faults and their relation to igneous activity, the relation of mineralization to these faults and to igneous activity, the metamorphism of the sedimentary rocks by igneous intrusion, the presence of a great series of dioritic sills, and the presence of a conglomerate of probable late Paleozoic age which has not heretofore been identified in this part of Idaho.
FIELD WORK AND ACKNOWLEDGMENTS

The field work began June 21, 1927, and continued until September 15 of the same year, when the autumn rains made further work inadvisable. During the interval, every mine and nearly every known prospect was visited. The first month and a half was spent in making a reconnaissance geologic map of the area, using as a base a Forest Service enlargement of the U.S. Geological Survey Priest Lake sheet. The map showed topography with a 200-foot contour interval which readily made approximate location possible, but because of the scale and other factors, the geologic boundaries in general could not be accurately fixed. The writer was assisted in the field by Mr. John Nicholson, a student in the School of Mines at the University of Idaho.

Courtesies extended by the many mining men while the writer and his assistant were in the field were highly appreciated. The assistance of Mr. Compton I. White of Clark Fork, who personally conducted the writer to many of the prospects, greatly facilitated work in the district, and his cheerful compliance with requests for maps and detailed records is especially worthy of acknowledgment.

The writer wishes especially to acknowledge his gratefulness to Dr. G. F. Loughlin of the U.S. Geological Survey for his critical reading of the manuscript and for his many helpful suggestions. The work in the office was speeded by the aid of Mr. William D. Mark, a student in the School of Mines at the University of Idaho, who assisted in preparing thin sections of rock and polished surfaces of ore for microscopic studies. The writer is also indebted to Mr. Stuart Udell, a graduate student of the School of Mines, for his careful drafting of the maps.

LITERATURE

Prior to the present investigation little has been recorded concerning the topography, geology, and ore deposits of the region. The chief source of information on the area is in the U.S. Geological Survey Bulletin No. 384, “A geological reconnaissance in northern Idaho and northwestern Montana,” by F. C. Calkins. This bulletin describes the stratigraphy and structure along the Clark Fork and Pend Oreille Lake and contains notes on some of the igneous rocks.

Following is a list of the more important articles and publications that have a bearing on the area concerned:


GEOLGY AND ORE DEPOSITS OF CLARK FORK DISTRICT


GILLIS, J. L., Geology of and ore deposits of the Pend Oreille district of northern Idaho: Jour. Geol., Vol. 56, pp. 1-44, 1927.

HUMPHREY, EDWARD, Geology and ore deposits of the Pend Oreille district: Idaho Bureau of Mines and Geology, Pamphlet No. 31, 1938.


GEOGRAPHY

LOCATION

The Clark Fork district lies along the Clark Fork of the Columbia River in the northern part of Idaho, about 35 miles northwest of the well-known Coeur d'Alene mining district and adjacent to the Pend Oreille district. Its location is accurately shown in Figure 1. The area lies wholly in Bonner County, having the Montana state line for its eastern border, Boundary County as its northern, and part of Shoshone County as its southern. The total area is about 580 square miles. Its position in relation to the Cabinet, Selkirk, and Coeur d'Alene mountains is shown in Figure 2.

The largest town in the district is Sandpoint, the county seat, which lies in one corner of the area. The mineral-bearing region is tributary to the town of Clark Fork, not far from the Montana line, and this town is considered the mining camp of the district. The locations of other towns are given on the maps.

ACCESSIBILITY

The mines near the town of Clark Fork are within easy reach of the main transcontinental line of the Northern Pacific Railroad, which follows the Clark Fork from Montana, through the towns of Clark Fork and Hope to Sandpoint and the west. The town of Clark Fork is the chief shipping point of the ores. An excellent surfaced highway, the Lewis and Clark, also parallels the railroad from the town of Clark Fork to Sandpoint. The producing properties and many of the prospects are joined to the town of Clark Fork by secondary roads which are generally passable throughout the year. Transportation is not difficult for deposits near the town of Clark Fork, but for those far back in the Cabinet Mountains, the problem is acute. Most of the area may now be reached with more or less difficulty by forest trails, but until 1927 the trails were few, and travel, except on the trails, was practically
impossible because of the dense forest growth. This has undoubtedly been a handicap to prospecting far from the main lines of travel.

The flat valley between the Cabinet and Selkirk mountains is traversed by two great railways, the main line of the Great Northern and the Spokane International. These pass through Sandpoint and follow the wide valley as far north as Bonners Ferry in Boundary County, but neither of these are adjacent to mineralized areas within the Clark Fork
district. Another trunk highway, the renowned North and South, also parallels the two railroads. Several logging roads extend well back upon the west slope of the Cabinet Mountains, but the area tapped is almost void of mineralization.

**TOPOGRAPHY**

The Clark Fork district is mountainous (Figure 2), except for the wide, flat-bottomed Purcell Trench, which extends through the district and separates the Cabinet Mountains from the Selkirks. This "trench" is the main physiographic feature of the district as well as of the entire region—a long, narrow, intermontane depression occupied by several streams and lakes alternately draining in opposite directions, and extending from Spokane, Washington, northward into Canada, where it joins the Rocky Mountain Trench, a similar intermontane depression, 200 miles north of the international boundary. A peculiarity of this trench is its generally flat bottom. It is long in proportion to its width, and its streams are divided by low water sheds which flow in opposite directions. The Purcell Trench is from three to five miles wide throughout its great length, but near Elmira, in the northern part of the Clark Fork district, it narrows to about one and one-half miles. It again flares widely to the south, where it opens fan-shaped, and near Sandpoint it is more than eight miles wide. South of the district the trench divides; one branch passing through Coosada Valley and the other along Pend Oreille Lake. They rejoin near the town of Athol to form the wide Rathdrum and Spokane valleys.

The flat valley floor is built up mainly of glacio-fluvial deposits, with here and there low hills of recessional moraine, and, near the west border of the trench, a low line of rock scoured hills which extend northward from Sandpoint to Samuels, a distance of eight miles. These rock hills (Figure 2) rise 200 to 300 feet above the alluvial plain, and lie about one and one-half miles from the east base of the Selkirk Range, separated from it by the flat, gravel-filled valley of Sandpoint Creek. Another isolated rock hill lies in the middle of the Trench at the north border of Pend Oreille Lake. Evidence of past glaciation is abundant within the great valley, as recorded by the glacio-fluvial deposits, the patches of recessional moraine, and the presence of erratics, one of which is a giant granite boulder more than 40 feet high (Plate II, B) resting on a base of ancient conglomerate a short distance east of Samuels. The sides of the great valley are scoured by ice and the strie indicate that the glaciers came from the north.

The Purcell Trench is without large streams in this district. The only stream within it, aside from Sandpoint Creek, is Fack River, which
flows diagonally across the Trench from the Selkirk Mountains, cutting a corner from the Cabinet Mountains before it enters Pend Oreille Lake at a temporary base-level. Pend Oreille Lake lies within one branch of the trench and is curved into the shape of an interrogation point or the crook of a shepherd’s staff. The surface of the lake is only slightly lower than the gravel-filled valley on the north, and only slightly below the terminal moraine which holds it in on the south. It is one of the largest lakes west of the Great Lakes, being about 42 miles long by 4 miles wide, ranging from one mile or less at the ends to six miles near the Clark Fork delta. The lake has a maximum depth of 1,100 feet, according to soundings made by Edward Sampson, formerly with the U.S. Geological Survey. It has a U-shaped bottom and many of the ridges which bound it are facets.

The three mountain ranges, the Coeur d’Alenes, the Cabinets, and the Selkirs, are alike. They represent uplifted plateau areas that have been maturely dissected by streams (Figure 2). In addition, the Selkirk and Cabinet mountains have been severely glaciated. Slopes are steep and ridges are narrow. The ridges in general have no particular arrangement or pattern, and their position is largely uncontrolled by the character of the underlying bed rock. Some of the streams, and particularly the larger ones, are controlled by structural features, and have carved their valleys along major zones of faulting where erosion has been rapid and relatively easy. Such is true of the Clark Fork Valley and the Purcell Trench.

Uniformity of summit levels is the most striking feature of the three mountain groups. Each, when viewed from the other, presents a nearly uniform skyline with here and there a peak rising slightly above its surroundings. The plateau-like character is best seen, however, in the Coeur d’Alene Mountains, where glaciation has not destroyed the symmetrical rounded forms of the ridges as it has in the others. The mountains are in the early stages of maturity, but glaciation within the Selkirk and Cabinet ranges has so serrated and steepened the ridges that they present an alpine appearance. The summit levels are not the same for each of the groups, but the summit of the Coeur d’Alene Mountains lies about 1,500 feet lower than that of the Cabinets directly across the Clark Fork Valley. This is explained, perhaps, by movement along the great Hope fault, which has raised the Cabinet summit surface when contrasted with the Coeur d’Alene Mountains on the south.

The Cabinet Mountains rise from 4,000 to 5,000 feet above Pend Oreille Lake, the Purcell Trench, and Clark Fork Valley. As indicated on the map (Figure 2), the range is cut deeply by valleys, most
of them with steep sides, and separated by ridges with sharp crests. Scotchman Peak, at the south border of the range, has an elevation of 7,011 feet A.T., and is the highest in the district. Goat Mountain, which lies on the west flank of Scotchman Peak and which shows a notable degree of mineralization, has an elevation of about 6,500 feet. The average altitude of the southern margin of the range is about 6,200 feet A.T. Northward the summit elevation decreases somewhat as though the surface were warped, but it increases again in the northern part of the district, attaining a maximum elevation of 6,785 feet A.T. in Pend Oreille Peak.

The Cabinet Mountains are most rugged in the vicinity of Scotchman Peak, and all peaks and ridges are distinctly alpine where viewed from the north, especially as each has a scallop of glacial cirques, as shown in Plate I, A, a feature that is generally lacking on the south slopes. These cirques reach their maximum size on the east and west sides of Scotchman Peak, where Sam Morris Creek heads in an immense cirque, whose floor, surrounded by precipitous walls on three sides, lies 3,000 feet below the summit of the peak. Another cirque nestles on the east side, but this is a hanging cirque, for a great glacier in the valley of the West Fork of Blue Creek cut deeply into the valley, and has left a border of amphitheater-like basins and hanging valleys, as illustrated in Plate I, B, some of them being 2,000 feet above the present valley floor. Some of the cirques in other parts of the mountains harbor small lakes.

Evidences of mountain glaciation are ample, but evidence also exists of an older glaciation that covered the range beneath a sheet of ice, except for some nunataks along its southern margin. Evidence of this is to be found in the presence of erratics reposing on the tops of peaks near the head of Lightning Creek at elevations above 6,500 feet A.T., and at elevations of about 5,000 A.T. on Goat Mountain and on the ridges above Hope and Trestle Creek. The surfaces of the ridges bear glacial striæ, all pointing in a southward direction. The flanks of the mountains bordering the Purcell Trench and the Clark Fork Valley also show glacial features of a younger and less extensive ice lobe that failed, however, to over-ride the mountains as did the earlier glacier.

Another striking feature of the Cabinet Range is its southern margin, where it borders the Clark Fork Valley. The range rises abruptly from the valley and presents a regular, bold, scarp-like wall rising about 4,000 feet above Pend Oreille Lake and extending from the Purcell Trench southeast many miles into Montana (Figure 2). This singular, straight border of the mountain outlines the course of the Hope fault,
which lies at its base, and the mountain front is really that of a partially eroded or exhumed fault scarp.

The trace of the Hope fault controls the general alignment of the Clark Fork Valley. A short distance east of the state line, however, the river swings to the south and isolates a low group of hills or mountains between the river and the depression that outlines the course of the fault, a group of low mountains that should more properly belong to the Coeur d’Alene system, but which are considered as foothills to the Cabinets. If the steep, south side of the Clark Fork Valley were taken as one boundary and the steep slope of the Cabinets on the north of the Hope fault as the other, a great valley or trench would be outlined in many ways similar to the Purcell Trench, with such streams as Cascade Creek, Spring Creek, Mosquito Creek, and Gold Creek flowing alternately in opposite directions for part of their courses along the fault depression, and with the low line of mountains in the center of the trench floor comparable but on a larger scale to the low hills in the Purcell Trench. The term “Clark Fork Trench” is probably justifiable in treating of this larger feature. It has an average width of about four and one-half miles.

This miniature mountain range in the great valley is in the special locus of mineralization. The most notable of these hills is Howe Mountain, a dome-shaped ridge, which attains an elevation of 3,800 feet A.T., and which extends between Denton Siding and Lightning Creek; Middle Mountain, which lies on the east side of Lightning Creek north of the town of Clark Fork; Antelope Peak, the highest of these, with an elevation of 4,400 feet A.T., and which adjoins the town of Clark Fork on the northeast; Sugarloaf Mountain, at the very base of the Cabinets near the Montana line, with an elevation of 4,000 feet A.T., and several lower unnamed hills nearby. These hills or mountains show strongly the scouring of an ice lobe, which, judging from the position of glacial drift, erratics, flutings, and striations, moved up the great Clark Fork Valley an undetermined distance into Montana.

The Clark Fork lies along the south side of the “Trench” and enters Pend Oreille Lake, in which it has constructed a large delta, and leaves the lake at Dover, a short distance west of Sandpoint, where it has entrenched across a low granite ridge. The river as it enters Idaho from Montana has cut a gorge more than a hundred feet deep through siliceous sedimentary beds. This gorge, known as the Cabinet (Plate II, A), has vertical walls less than one hundred feet apart, and has considerable local renown because of its ruggedness and beauty. The river delta heads about three and one-half miles west of the gorge and
A. GLACIAL CIRQUES IN THE CABINET RANGE

The north slopes of the ridges are fringed with glacial cirques, and bear witness of lingering mountain glaciers after the retreat of the youngest lake of ice from the Purcell and Clark Fork trenches in Pleistocene time.

B. GLACIATED VALLEY OF BLUE CREEK

Tributary valleys are suspended high on the sides of Blue Creek valley as a result of deepening and widening of the larger valley by a valley glacier. Some of the hanging valleys are as much as 2,000 feet above the main valley floor.
A. CABINET GORGE
Probably an adjustment to glaciation in which the Clark Fork was superimposed on a ridge of the siliceous Striped Peak formation.

B. GLACIAL ERRATIC IN PURCELL TRENCH
A boulder more than 40 feet high was left by the last ice lobe in the Purcell Trench a few miles north of Standpoint. Glacial drift in the lower country is a great handicap to prospecting.
has filled in the arm of the lake a distance of seven miles. The delta has the usual interesting array of distributaries or delta fingers, natural levees, and is subject to floods during high water.

Little need be said of the Selkirk Range or the Coeur d'Alene Mountains in this report. The Selkirk Range is as highly sculptured by past mountain glaciers as the Cabinet Range and gives evidence of having been over-ridden by a great ice sheet modified later by a lesser lobe, which scoured its sides, steepening and faceting its ridges where it borders the Purcell Trench. Mt. Casey at 6,735 feet A.T. is the highest point of the range within Bonner County, but northward higher elevations are attained. The Coeur d'Alene Mountains have largely escaped the glaciation that has so affected the others. A few mountain glaciers hung on the north slopes of some of the peaks and ridges, but the area is free from the general glaciation except along its northern border. The average elevation of the Coeur d'Alene Mountains in Shoeshone County is about 6,000 feet, but a northward tilt lowers this general level of the summits to about 5,500 feet at the Bonner County line. The northern border of the Coeur d'Alene Mountains is exceedingly precipitous, with nearly vertical cliffs rising as much as 2,000 feet above Pend Oreille Lake and the river, the result of glacial faceting. The upper limit of the ice of this valley lobe stands at about 4,000 feet A.T. near the lake, and decreases gradually up the valley. Evidence of an older glacial advance is also found on the north slope of the Coeur d'Alene Mountains, following closely the 5,000-foot contour. This probably represents the margin of the earlier glacier that completely over-rode the Cabinet and Selkirk mountains.

VEGETATION AND CLIMATE

Except the highest summits and ridges, all the area is, or recently was, clothed with a dense forest and denser underbrush. Lumbering is the chief industry of the district, and, except for farms and ranches on some of the cut-over lands in the Purcell Trench and Clark Fork Valley, constitutes the chief source of income for the people. Nearly one-tenth of the people depend almost directly on the timber resources for a livelihood. Several large mills are operating at Sandpoint, Kootenai, and Dover. White pine is the most valuable timber in the district, but yellow pine, cedar, hemlock, larch, and fir are more abundant and furnish the greater supply for most of the mills. Timbers for mining purposes are everywhere abundant, and wood is used for raising steam in boilers at isolated mining plants.
The vegetation, rather than being an aid to mining, has proved a serious handicap. The dense brush and forest growth has hindered prospecting, by making travel exceedingly difficult, and by effectively clothing and hiding the bedrock, thus making discovery of mineral veins difficult.

The luxuriant growth of vegetation is aided by climatic conditions, a rainfall that averages about thirty inches a year scattered throughout all the months, although with a tendency to a summer drought, a growing season between mid-May and mid-September, and no great extremes in temperature. The winters are not particularly severe and zero weather is rare. The winter snow is deep in the higher mountains and lingers late in the summer, but it does not seriously interfere with mining operations near the town of Clark Fork, where the fall is lighter. Prospecting may be carried on during about four months of the year in the higher altitudes and lengthened to more than six months on the lower slopes.

POWER

The district is well served with power. An electric transmission line is built from Sandpoint to the town of Clark Fork, and this is of ready and easy service for the mines. The streams in the mountains have steep gradients, and, owing to the retarding effect of the vegetation, can be used to furnish ample power in the more isolated part of the district. Wood may also be used to raise steam in boilers at the smaller mine plants.
GENERAL GEOLOGY

GENERAL FEATURES

The geology of the Clark Fork district resembles in many ways that of the famous Coeur d'Alene district about 35 miles to the southeast. A large part of the area is underlain by rocks of sedimentary origin of late pre-Cambrian (Algonkian) age and known more generally as the Belt series. These show some differences from the rocks described in the type localities or from those described in the Coeur d'Alene district, but the differences are not too great to prevent correlation. In general the members are much thicker here than farther south and east.

In addition, there is a conglomerate, younger than the Belt series, which is not found in the Coeur d'Alene district. This formation, so far as can be determined in the Clark Fork district, is probably late Paleozoic in age, and its occurrence is one of the interesting features of the geology of the region. It rests unconformably upon the eroded surface of the lower Belt (Prichard) and is composed largely of material from the Belt terrane and possibly has some boulders from the Cambrian. It is intruded by Jurassic granodiorite, and for reasons given later is believed to be the result of orogenic disturbance in late Paleozoic.

The principal difference between the Coeur d'Alene and the Clark Fork districts is the much greater abundance of igneous rocks in the Clark Fork region. Here occur igneous rocks of two widely separated ages, the older a great series of intrusive sills of dioritic and gabbroic composition, which lie as thick sheets between the bedding planes of the lower Belt (Prichard). These were apparently unaccompanied by mineralization in this district, but furnish an interesting problem for scientific study because of their great persistency and abnormal chemical and mineralogical composition. The younger igneous rock, mainly of granodiorite composition, is intrusive into all the rocks mentioned above and forms a large batholith in the Selkirk Range and a smaller one on the west slope of the Cabinet. Smaller stocks appear in the Cabinet Range, and these are of interest because they, together with concealed bodies, form the source of the mineralization of the district. These stocks and batholiths are generally surrounded by a border fringe of porphyry dikes, and they have also given off a host of dark lamprophyric dikes of several kinds that only slightly preceded and antecedent the mineral veins in point of age.

The metamorphism of the sedimentary rocks induced by the intrusion of granodiorite is worthy of particular note in that the degree of
schistosity or metamorphism is dependent on the "wetness" of the magma as reflected by the relative abundance of pegmatite in the granodiorite and about its borders. The metamorphism appears to increase directly with the number or abundance of pegmatite.

In structural features, the Clark Fork district greatly resembles the Coeur d'Alene district, where great east-west faults, the largest of which is the Osburn fault, control the structure. In the Clark Fork district, the Hope fault, a similar earth fracture of great magnitude trending northwest along the lower slope of the Cabinet Range, is the dominant structural feature of the whole area. In addition, the region has other faults of unusual magnitude, some of them with the largest trend in a northerly direction, and others arranged in mosaic pattern about the borders of the larger granodiorite bodies.

The larger structural features are shown on the geologic map, but most of the details and the less pronounced features have been omitted because of the limited time devoted to the study of the district as a whole, and also because of many inaccuracies of the base map which has made detailed mapping impossible. Most of the faults that are the result of readjustments within the intrusive magma or that are due to the force of the intrusion itself have been left off the map as a consequence of which the fault mosaic is but poorly shown, except possibly along the Purcell Trench. Some of the large faults have probably been overlooked, for the lithologic character of the rocks is so unusually similar through hundreds and even thousands of feet of section that the recognition of faults of less than a few hundred feet displacement is in most places impossible. The scarcity of good exposures in some large areas makes it impossible to work out the structure with anything like completeness. The dioritic sills in the lower Prichard are excellent in determining faulting, but because of their number and great similarity they are generally unsuitable as horizon markers to determine the magnitude of displacement.

Again, in the character of the mineralization and the type of ore bodies, the two districts are greatly similar. The minerals of the Clark Fork district are essentially the same as those in the Coeur d'Alene district, and the ore bodies are also mainly replacement veins.

SEDIMENTARY ROCKS

The sedimentary rocks of the district fall into three groups: the Belt series of Algonkian age, the Sandpoint conglomerate of late Paleozoic(?), age, and the deposits of Pleistocene and Recent age. The several groups are readily distinguished. Of these, the Belt series is the most
widely distributed and is the most important because it furnishes the base for most of the mineral deposits. It is easily recognized in the field by its fine grained, bedded character, composed for the most part of a thick assemblage of shales and sandstones, and of argillites and quartzites, with a great thickness of calcareous members near the middle or upper part. This is in marked contrast with the coarse, bouldery, Sandpoint conglomerate of younger age. The latter may be confused with some of the bouldery Pleistocene and Recent deposits, but the older conglomerate is well cemented and is without granodiorite and porphyry boulders, whereas the younger is generally unconsolidated and has a different assortment of material, particularly a high proportion of granodiorite and porphyry boulders.

ALGONKIAN SYSTEM

The Algonkian or Belt rocks have a great thickness in the Clark Fork district, probably more than 40,000 feet, although no time was found for accurate measurements. Much more of the lower part of the series is to be found in the Clark Fork district than in the Coeur d'Alene, but here, too, the actual base is not brought to view. Throughout its great thickness the series is composed of shallow water deposits with sun cracks and ripple marks abundant in some parts, but scattered to greater or less extent from the base to the top. Another of the notable characters of this great thickness of sediments is the lack of appreciable metamorphism except in the vicinity of intrusive granodiorite, and most of the rocks are sandstones and shales, rather than quartzites, argillites, or schists.

As in the Coeur d'Alene district the great series may be sub-divided into several formations, but in the absence of fossils these divisions must be based on lithologic grounds alone. Fortunately, the stratigraphic column falls into natural divisions, each characterized by certain lithologic features of diagnostic value, although this separation is not always as easy as a description of the formations might indicate. Without exception, contiguous formations grade one into the other, and they all succeed one another conformably. Although each formation is a well individualized unit, the precise horizons of the division planes that separate them are matters for somewhat arbitrary decision. To sum up, it should be stated that it is not everywhere easy to distinguish the formations until some experience with them has been gained. Even a familiarity with the rocks of the nearby Coeur d'Alene district is not a thoroughly reliable basis for distinguishing them, and
it is only by the careful examination of all the Belt rocks present in
the district that these minor features, which are truly characteristic, can be appreciated, for the outstanding feature of all the formations is their marked resemblance to one another.

In sub-dividing the Belt series in the Clark Fork district, the Coeur d’Alene nomenclature (Prichard-Burke-Revett-St. Regis-Wallace-Striped Peak) is used. The older nomenclature employed by Calkins\(^1\) (Prichard-Ravalli-Newland-Striped Peak) is probably to be preferred, but the Coeur d’Alene names are so firmly established in northern Idaho and are so familiar to those interested in the mineral industry of the state that they have been given preference. Full description of the formations is not called for here, but the distribution and characteristic features of each are presented for the benefit of those interested in the development of the district. All members are represented except the Revett, which cannot be distinguished from either the Burke or St. Regis, and is therefore omitted from discussion. They are described in ascending order.

**PRICHARD FORMATION**

The Prichard formation is the oldest member of the Belt series, and, in this district, the thickest. Measured across the strike near the south margin of the Cabinet range between Goat Mountain and Hope, the prevailing eastward dip averages about 28° for a distance of 12 miles, indicating a thickness of more than 20,000 feet. As the base of the formation is nowhere exposed in the area, its exact thickness is unknown and is probably much greater than that given above.

The formation is largely composed of argillaceous sandstone with some shale, and is in general more arenaceous or siliceous than the corresponding formation of the same name in the Coeur d’Alene district. Only the upper 1,500 feet of the formation on Goat Mountain are conspicuously shaly and bear resemblance to the typical Prichard “slate” of the Coeur d’Alenes. The remainder consists of gray quartzitic sandstone, interbedded in places with some nearly pure quartzite members, and with subordinate shale. Minor lenses of intraformational conglomerate may be found near the middle of the section in some of the quartzite and sandstone beds. A thick bed of sandstone that weathers grayish to white and similar to certain members of the overlying Burke formation lies near the top of the section, but this is overlain by the 1,500 feet of the dark blue banded shales, and underlain

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by another series of bluish gray laminated shales and thinner beds of sandstone and quartzite. The Prichard and overlying Burke formation are similar in many respects, but the Prichard formation may be distinguished by being darker colored and by its weathering to a rusty color, particularly along fractures.

The Prichard is the only member of the Belt series in the Clark Fork district to be found in contact with granodiorite, and is hence the only one to show pronounced effects of contact metamorphism. Near granitic intrusives the shales have become argillites or mica schists, and the argillaceous sandstones have been converted into mica schists and micaeous quartzites. Where metamorphism has not been severe, sun cracks and ripple marks are preserved in many horizons throughout the formation, but these features are not as abundant as in the upper members of the Belt series.

The Prichard has the widest distribution of any member of the Belt series, as most of the Cabinet Range within the district is of this formation. Most of the formation therefore lies on the north side of the Hope fault, except for a small patch of these rocks on the west tip of the peninsula and on the three islands south of Hope. Several exposures occur in the Purcell Trench, but these, like the Prichard east of Elmira in the northern part of the district, are considerably metamorphosed by the granitic intrusions and are not easily identified without extensive traverse.

**BURKE FORMATION**

The Burke formation in this district is composed of fine grained sandstones in massive beds or as thin beds with argillites. Sun cracks and ripple marks are common. The sandstones are prevalingly gray with a greenish cast. The formation differs from the upper part of the Prichard only in being somewhat more siliceous. It may be easily confused with the underlying Prichard, but the weathering is one of its most characteristic features, for the weathered surface is a light clear gray in rather marked contrast with the fresh rock and with the rusty appearance of the weathered Prichard. The Burke may also be confused with some of the overlying members of the St. Regis and with parts of the still younger Striped Peak, but the younger have other diagnostic features and none of them weather in color as does the Burke.

The Burke is best exposed on Scotchman Peak north of the Hope fault, where it overlies the Prichard, and on the peninsula south of the town of Hope. A good section is afforded for study at either place, for
on Scotchman Peak the cirques are carved in this rock, and on the peninsula the shores of the lake have been swept clear of detritus by the waves, making satisfactory bed rock exposures at both places. The formation is apparently about 3,500 feet thick, but this thickness may also include the equivalent of the Revett of the Coeur d'Alene district, which cannot be here satisfactorily identified. The first appearance of the pinkish markings was taken to indicate the boundary between the Burke and the overlying St. Regis.

ST. REGIS FORMATION

The St. Regis formation may be identified with somewhat greater ease than the other formations, because of the reddish or reddish-purple color of many of its members. The lower part of the formation is prevalingly quartzitic or composed of quartzitic sandstones, in part feldspathic, very much like the underlying Burke formation, from which it may be distinguished, however, by the faint pinkish color of some of its beds or by thin partings of red shale. The lower beds are softer and thinner, but the rocks near the center of the formation are more massive and more resistant to erosion. Higher in the series are some beds of massive quartzites with greenish tints passing into beds with delicate purple bands. The upper St. Regis beds are alternating red and green shales and argillites with the red predominating.

The red argillite, or shale, occurs only as partings in the lower part of the formation, but makes up an enlarging portion of the whole as the upper parts of the formation are reached. Many of the thin partings are more or less continuous fine reddish laminations, and, where sufficiently continuous, break along the bedding planes showing glistening micaceous surfaces, very much ripple marked. Single outcrops may consist entirely of greenish argillite or quartzite, but most large exposures show the red or purple beds which characterize the formation. The greenish argillite that forms the top of the series is with difficulty distinguished from the bottom of the conformably overlying Wallace formation. The whole St. Regis formation has sun cracks and ripple marks, which are particularly abundant in the greenish and reddish shales and argillites in the upper part. The St. Regis might easily be confused with the younger Striped Peak formation, which also has many reddish beds, but the character of the rock differs somewhat, for the Striped Peak is mainly reddish sandstone and reddish shale, alternating with olive-colored sandstones and shales, and lacks the general quartzitic character of the older rocks.
The St. Regis formation is best exposed on the peninsula southeast of Hope and on the west flank of Howe Mountain, where it conformably overlies the Burke. A part of the section may be studied along the lake shore and a part on Howe Mountain, but the section is not quite complete, as some of it is buried by alluvium. In all, more than 7,500 feet of beds may be measured, and this formation, like the others beneath it, is thicker than the corresponding formation in the Coeur d'Alene district. A small exposure of this formation may also be found north of the Hope fault in the canyon east of Scotchman Peak.

WALLACE FORMATION

The Wallace formation is the one which most closely resembles its equivalent in the Coeur d'Alene district and is the most easy to identify, although even here considerable care must be exercised. The outstanding feature of this formation is the presence of calcium carbonate distributed through the rock in such a manner that the weathered surfaces show peculiar and easily recognized structures. The Wallace formation is the most heterogeneous of the Belt series, composed throughout of fine grained, thin bedded rocks, which comprise green, more or less calcareous shales, blue and white banded argillites in part calcareous, light gray and yellowish weathering calcareous quartzites, patches of pure lime carbonate, and pure quartzite. All types are connected by gradations, and the entire accumulation has abundant sun cracks (Plate III, A) and ripple marks.

Near the bottom the formation is a dense, flinty green argillite; higher up it passes through thin bedded greenish argillites and thin, massive quartzite layers with thin beds of impure limestone repeated again and again so that no horizon is distinctive. Near the top it passes into a series of greenish shales and thin bedded quartzites with partings of lustrous dark green shale which in turn passes into impure limestone and argillite, made up in part of shale in very thin blue-gray and white layers and partly of gray-green homogeneous argillite. This in turn passes into a thin series of reddish sandstones very like the overlying Striped Peak, but changes again to a bed of impure massive limestone several feet thick and with more calcareous quartzite and argillite. The last limestone member is taken as the top of the formation, for above this lies the reddish and greenish banded Striped Peak. Parts of the Wallace formation are similar to the greenish argillites and to the greenish quartzitic beds in the Burke, St. Regis, and in the Striped Peak, and only by going up or down in the section can identity be established. This is most easily made from the weathered surfaces
of the calcareous facies of the formation, for the lime weathers out and leaves peculiar cellular forms such as illustrated in Plate III, B. These forms are so characteristic that they are recognizable even in small fragments of surface debris and indicate the presence of underlying Wallace where no outcrops occur. The lustrous dark green shale partings are also diagnostic, for no other formation contains them. Many of the beds weather to a characteristic brownish-yellow color that is also useful in identifying this formation.

The Wallace formation is found only in the downfaulted beds on the south side of the Hope fault and composes the greater part of Howe Mountain where it conformably overlies the St. Regis. It also composes a large part of Middle Mountain and the lower part of Antelope Peak where it lies beneath the Striped Peak formation. These beds extend across the Clark Fork and have wide distribution in the Coeur d'Alene Mountains. The formation is of particular interest as the present valuable lead-silver deposits occur in it. The formation is not easily measured because of faulting, but more than 6,000 feet of beds are exposed. It, too, is thicker than its equivalent in the Coeur d’Alene district.

**Striped Peak Formation**

The Striped Peak formation, as previously mentioned, is apt to be confused with the St. Regis formation in this district, because it has many reddish members, including reddish sandstone and reddish shales. The color differs, though, in that the purplish tint, which is so characteristic of some of the markings in the St. Regis, is lacking. This formation shows great lithologic changes in a very short distance, for in the adjoining Pend Oreille district¹ and even in the west part of the Clark Fork district the reddish color of the beds has wholly disappeared and the beds are mainly olive drab. As a whole, however, the formation is very like that in the Coeur d’Alene district and in Montana.

The base of the formation is composed of several hundred feet of particularly thin bedded, nearly fissile, shales, some of which are slaty and have a greenish and bluish color. These lie conformably above the thick limestone member which forms the top of the Wallace formation. Above is a great thickness of reddish sandstone and shale beds, alternating with greenish shale and argillite beds. Some of the reddish horizons range from a few feet to as much as 800 feet in thickness, separated by beds of greenish or olive drab rock 50 to 200 feet thick. The reddish beds disappear higher in the formation, and, so far as can

A. SUN CRACK PATTERN IN WALLACE FORMATION

The sun crack pattern is characteristic of a certain bed near the middle of the Wallace formation. Sun cracks of somewhat different appearance are distributed throughout the entire Belt series.

B. CELLULAR WEATHERING OF THE CALCAREOUS BEDS IN THE WALLACE FORMATION

These cellular relics caused by the leaching of the lime as a result of surface weathering are useful in identifying the Wallace formation. Such forms are scattered throughout the Walls.
A. SANDPOINT CONGLOMERATE

A typical exposure of the Sandpoint conglomerate, a formation new to north Idaho. It was deposited under torrential conditions from mountains built probably near the close of the Paleozoic.

B. DETAILS IN THE SANDPOINT CONGLOMERATE

The angularity and subangularity of the boulders, which characterize this formation, is evident. These boulders are from the Belt terrane, mainly quartzite but in places include much quartz diorite from the sills. The boulders are poorly sorted and extremely well cemented.
be judged from this district, only extend about 3,500 feet above the base. The sandstones are micaceous throughout with glistening muscovite flakes along bedding surfaces. The reddish and greenish shales are also generally micaceous. The olive drab color of some of the beds is generally characteristic of the formation, especially as weathering accentuates this color. Some laminated argillite of thin alternating dark gray and yellowish bands, very closely spaced, also occur in the formation, and these have useful diagnostic properties where the red beds do not occur. Parts of the Striped Peak, especially near the west margin of the district, might be confused with the underlying Wallace, but the absence of lime helps to distinguish the formation. Ripple marks and sun cracks are abundant throughout the formation. As a whole, this formation is less quartzitic than any of the others, and shows the least degree of metamorphism.

The Striped Peak occurs on the south side of the Hope fault to the east of the area of Wallace rocks. Antelope Peak owes its reddish hue to the color of this formation, which forms its upper half. The Cabinet Gorge is cut through some of the olive-colored, siliceous argillites of this formation. The red beds are beautifully exposed in the canyon of Dry Creek along its east branch south of the town of Cabinet, in a series of reddish cliffs about 850 feet high. A good exposure of the red and green beds is also afforded along the east side of the valley of Deyle Creek. A block of this formation also lies west of Johnson Creek, where it has been faulted along side the Wallace formation. In this place, however, the reddish beds are wholly lacking and the character is much the same as in the Pend Oreille district a short distance to the southwest. More than 4,000 feet of beds are exposed in the Clark Fork district, and the top has been eroded. Sampson reports more than 9,000 feet of this formation to the west, nor is the section complete in that district.

PALEOZOIC ROCKS

SANDPOINT CONGLOMERATE

In the Pend Oreille district the Striped Peak is overlain by Cambrian rocks, presumably separated from it by a great break in the sedimentary record, but, so far as can be determined from insufficient exposure, with apparent conformity. These Cambrian rocks, comprising limestones, quartzites, and shales, outcrop near the lower end of Pend Oreille Lake,¹ where they have been downfaulted against mem-

¹ Sampson, Edward, op. cit., pp. 9-10.
bers of the Belt series, but no rocks of this character were found in the Clark Fork district. However, a formation that is apparently younger than the Cambrian rocks lies in the Purcell Trench north of Sandpoint. This formation, a conglomerate deposited under torrential conditions in a great valley carved in the Belt terrane, is probably of late Paleozoic age, and presumably was deposited near the close of the Carboniferous. The conglomerate has been given the name "Sandpoint Conglomerate," because of its occurrence near the town of Sandpoint.

CHARACTER OF THE CONGLOMERATE

The conglomerate is at least 4,000 to 5,000 feet thick where it is exposed in a low hill on the east side of the Trench. As the top of the conglomerate has been removed by erosion, the exact thickness may never be known. The conglomerate has a northerly trend, and, along the east side of the Trench, a dip to the east of about 25°. The formation in general has been much disturbed by faulting, and, because it shows such great variation in its nature in very short distances, the exact thickness that remains cannot be accurately pieced together. In several places the conglomerate rests upon the eroded surface of the Prichard formation, and in one place upon a dioritic (pre-Cambrian) sill.

The conglomerate is extremely variable in texture, and is composed dominantly of boulders ranging from above gravel size to three and four feet in diameter embedded in a fine siliceous or sandy matrix. The average size is from six to twelve inches. The percentage of boulders to matrix is variable, but most of the conglomerate may be described as a compact boulder mass, as shown in Plate IV, A. Along or across the strike the boulders may change rapidly from average to greater or smaller size. The boulders are in general larger in the exposures on the east side of the Trench than in those on the west, suggesting that their source has been to the east of their present location. The boulders are extremely well cemented. In only a few places are small lenses of quartzite and slate noted. Bedding is everywhere difficult to determine, especially in the massive beds of conglomerate, but erosion has accentuated the differences in structure in places and has carved deeper into the tilted beds of less conglomeratic character.

The materials composing the conglomerate have not traveled far and in all cases can be identified with the members of the Belt series and the associated dioritic sills. The boulders are mainly angular and subangular, indicating rapid erosion and transportation with but little opportunity for wear (Plate IV, B). They are mainly of quartzite,
diorite, and lesser amounts of sandstone, argillite, and limestone. The largest seen are diorite in every way identical with the rock in the sills which are so numerous in the Prichard formation. In some places the diorite predominates over any other kind, but usually the quartzite is most abundant, and the change from one to the other may occur with great rapidity. Limestone boulders are local in their occurrence, and the softer argillites are also scattered, usually in large angular blocks. Much of the quartzite has been derived from the Prichard formation, some showing the same micaceous bands as the Prichard, which suggests that the lower Belt was in part metamorphosed before the conglomerate was deposited. Quartzite with the grayish-green cast characteristic of the Burke may also be recognized and forms a goodly share of the conglomerate. Purplish or reddish banded quartzites typical of the St. Regis are also present. The softer argillites and sandstones, as mentioned before, are confined only to the large angular blocks which have suffered little transportation, and in these may be recognized fragments of the reddish banded argillites of the St. Regis, the reddish micaceous sandstones and greenish or olive drab argillites of the Striped Peak, and greenish blocks of argillite or shale, possibly from the Wallace as well as some of the calcareous members. White limestone cobbles were also seen, especially near the south end of the outcrops, and these greatly resemble the Cambrian limestone near the south end of Pend Oreille Lake. Possibly these boulders may be Wallace, but they are unlike any of the impure beds studied to the east. The slight discordance between the Cambrian and Striped Peak represented a few miles to the south of the conglomerate, and the great angular unconformity existing between the Sandpoint conglomerate and the Belt also favors the supposition that the limestone cobbles are Cambrian.

**Origin of the Conglomerate**

The size and shape of the boulders, the usual poorly sorted character of the formation as a whole, and the evident derivation of the boulders from the immediately underlying Belt series and igneous sills indicate that the materials were not transported any great distance. The surface on which the conglomerate rests is fresh and irregular in outline, thus indicating that it had been subjected to rapid erosion. The conglomerate is undoubtedly of terrestrial origin and in some ways resembles tillite, but the apparent lack of faceted boulders and of glacial scratches and grooves precludes such a possibility. The possible marked variation in thickness, the rapid variation in composition, and the decrease in size of the materials from the east to the west sides of
the exposures suggest a fan structure or a conglomerate, in which the materials were carried by swift streams from an area of marked relief on the east, where conditions favored rapid erosion and deposited on the lower slopes of a basin or valley at its base.

AGE OF THE CONGLOMERATE

The age of the conglomerate can not be accurately fixed by its relations within the district, but its deposition is recorded within certain definite limits. Its youngest possible age is determined by the diastrophism which caused it to be folded, faulted and invaded by batholithic magmas along with the Belt series and associated sills. The orogenesis and its accompanying igneous invasions came during the Cordilleran revolution at the close of the Jurassic period, and the conglomerate can be no younger than the intrusions which Rose\(^1\) has only recently shown to be of late Jurassic age. Its oldest possible age may be determined from the rocks within the region. It has been repeatedly stressed that the materials of the conglomerate have been derived from the Belt series of Algonkian age, from the sills of late Algonkian\(^2\) (post-Belt) age, and possibly from the Cambrian. The relations within the district favor a post-Cambrian and pre-Jurassic age for the conglomerate.

Late Paleozoic diastrophism is recorded with varying degrees of intensity in many parts of the West, and it is believed, that for the region of north Idaho, mountains of sufficient height to cause vigorous erosion were formed and that the Sandpoint conglomerate is a consequence of erosion of such mountains produced at that time.

QUATERNARY SYSTEM

Sedimentary rocks younger than those described above occur in the Clark Fork district only as glacial deposits of Pleistocene age and recent stream deposits. In the Purcell Trench south of Pend Oreille Lake and a short distance west of Hayden Lake, the Latah formation of Tertiary (Middle Miocene) age comprises a series of old lake beds more than a thousand feet thick, capped by Columbia basalt; but this series has apparently been eroded from the valleys of the Clark Fork district. If there be any remnants of it, they are effectively hidden by the more recent deposits. The younger glacial and stream deposits have no particular economic significance, except that they conceal large areas of

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the older formations which may contain valuable ore deposits. No attempt is made to distinguish between the Pleistocene and the Recent deposits on the geologic map, and the only recent deposits that can be so differentiated are the flood plain deposits of Pack River and the delta deposits of the Clark Fork.

PLEISTOCENE DEPOSITS

These deposits comprise patches of recessional and ground moraine in the Purcell Trench, stratified glacial outwash also in the Trench and in the Clark Fork Valley, and unassorted glacial till and erratics that covers much of the bedrock of the district. Only where the underlying bedrock is greatly in doubt has the till been mapped as "Pleistocene and Recent." The low mountainous area between the Purcell Trench and the crest of the Cabinet Mountains is deeply covered with drift, and the older valleys have been literally filled with deposits which the present streams have as yet been unable to remove. The Purcell Trench owes its flat floor to the glacial fill, whose thickness is unknown, but because Pend Oreille Lake has a depth of 1,100 feet, the deposits in places may be equally as thick. In the Purcell Trench the surface gravels are unconsolidated, but some of the terrace gravels, and especially some great terraces along the Clark Fork, are well cemented and have very steep banks, especially in the railroad cuts. The gravels, whether stratified or not, are composed of rounded to angular pebbles and boulders derived from the surrounding higher lands, although much of it has probably been carried in from many miles to the north by the glaciers. The pebbles, sands, and boulders are thus made up of quartzite, argillite, granodiorite, diorite, etc. Much sand has been left in some parts of the Trench where ponding of former streams occurred. If the deposits were studied in detail, it would probably be possible to differentiate them as to early glacial gravels, later gravels, outwash gravels, moraines, and thus work out a more detailed glacial history.

RECENT DEPOSITS

The recent deposits are composed for the most part of reworked glacial material along the stream channels. The silts and sands along Pack River where it crosses the Purcell Trench to Pend Oreille Lake and the delta of the Clark Fork are the most notable deposits since Pleistocene time. These deposits are forming at the present day. The material is composed of fine grained sands and silts, which up valley becomes coarser and finally bouldery.
IGNEOUS ROCKS

The igneous rocks of the district fall into two main groups widely separated in age. The older of the two is a series of thick, tabular sills between the bedding planes of the Prichard formation. These have been invaded by the younger intrusions. The latter occur in the form of dikes, stocks, and batholiths. The older rocks differ greatly from the younger rocks not only in manner of occurrence, but also in the kind of magma from which the rocks have crystallized. The older rocks are dominantly dark colored and have for the most part the composition of abnormally quartz-rich diorites. The younger granitic rocks are lighter in color and have the composition of granodiorite. Both show differentiated facies, but neither the main varieties of each nor their differentiates are likely to be confused in the field.

ALGONKIAN (?) SYSTEM

MANNER OF OCCURRENCE

The sills are confined to the middle and lower part of the Prichard formation, and are thus to be found in the vast area of Prichard rocks north of the Hope fault in the Cabinet Range and in the faulted blocks in the Purcell Trench. These tabular bodies range from 20 to 2,000 feet in thickness and trend for many miles along the strike of the sedimentary beds. The thickest sills occur in the lower part of the Prichard formation, where one in the Purcell Trench measures 2,000 feet. Several sills along the crest of the Cabinet Range reach a maximum thickness of 1,500 feet. The thickness is not uniform and some of the greater sills decrease to 600 feet along the strike. A few sills occur in the upper Prichard, but these are only 20 to 30 feet thick and were not mapped.

More than a dozen separate sills occur in the district, but the exact number cannot be determined except by the closest detailed mapping. The sills show so little change lithologically that members on opposite sides of a fault cannot be safely correlated by either megascopic or microscopic means, and because of variation in thickness along the strike, widely separated masses cannot be correlated on the basis of size or distribution. Small engulfed masses or pendants may be found in the younger bodies of granodiorites.

One of the most remarkable features of these sills is their great persistency along the strike. Some of them were traced for 21 miles along the crest of the Cabinet Range to the boundary of the district. Their only interruption seems to be due to faulting. The sills have
A. PHOTOMICROGRAPH OF THIN SECTION OF DIORITE SILL ROCK
WITH NORMAL TEXTURE
This picture shows the normal relationship between the plagioclase (gray mineral) and quartz. Notice the abundance of quartz, a feature that characterizes these rocks. Crossed nicks.

B. PHOTOMICROGRAPH OF THIN SECTION OF DIORITIC SILL ROCK
WITH MICROPHEGMASSITIC TEXTURE
This relation of the plagioclase (gray mineral) and quartz (light mineral) is very common in the rocks. Usually the quartz predominates in these intergrowths, another abnormality of the sill rock. Crossed nicks.
been traced into Boundary County and across Boundary County into Canada. In Boundary County as many as 17 sills have been mapped and one of these was traced for 34 miles within the county before it was terminated by faulting, and its offset continuation extends an unknown distance into Canada. These sills have also been described in the Pureell Range in Canada, as the Moyie sills by Daly and as the Pureell sills by Schofield. Their northerly extension remains undetermined. In the Clark Fork district the sills end on the south against the Hope fault, but Calkins mentions their occurrence again in the Prichard formation, south of Sandpoint, and the writer has found them east of Coeur d'Alene city and in the St. Joe River region and the Clearwater Mountains still farther south.

Most of the intrusive masses can be clearly recognized as sills, as they are conformable with the sedimentary beds and their contacts may be studied in the valley sides or ridge tops, and in the walls of the glacial cirques. Because of their superior resistance to erosion, they are generally exposed in peaks, ridges, or cliffs and can be traced across the higher mountains by the belts or bands of brownish talus. Only two bodies in the district were recognized as cross-cutting the sediments, both of these near the south margin of the Cabinet Range.

AGE OF INTRUSIVES

The sills have been folded and faulted after their injection into the flat lying sedimentary strata and have consequently taken part in all the orogenic movements which have affected the region. The earliest diastromism distinctly recognizable occurs at the close of the Jurassic system, but as the sills have furnished material in the Sandpoint conglomerate they are at least older than late Paleozoic. On the other hand, they are generally confined to the oldest known member of the Belt series, although in Boundary County three were found in the Burke-St. Regis formation, and in the St. Joe River basin in Shoshone County one occurs in the middle of the Wallace formation and another near the top. These relationships indicate that the intrusions occurred in a post-Wallace epoch, and because the Striped Peak and possibly

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2 Daly, R. A., Memoir No. 38, Part I, Canada Geol. Surv., pp. 221-236, 1913.
6 Kirkham and Ellis, op. cit., p. 57.
the Cambrian formations overlie the Wallace in conformable succession, they may have taken place in post-Cambrian time. It seems improbable that the injection of 10,000 feet of igneous material along the bedding planes should not show some reflection in later sedimentation by slight angular unconformities, especially as the sills do not have a uniform thickness along their strike; but until more positive evidence is available, the time of intrusion as accepted by the workers to the north is placed at the close of the Algonkian.

**COMPOSITION OF ROCK**

The main mass of each intrusive body is composed of a notably uniform type of rock and little or no difference can be detected from sill to sill. The rock in general is dark in color, varying from gray to dull greenish black, depending on the proportion of dark and light minerals. Usually it is greenish gray and of medium grain, but the grain varies from fine to coarse where rock with crystals one-eighth of an inch long or less merges with rock whose crystals, especially the dark minerals, are three-quarters or even an inch long. The principal variations in megascopic character are due either to the local coarsening of grain or to a local development of a facies richer in dark minerals than the type.

Nevertheless, many of the sills show changes in texture, color, and mineralogy indicative of changing composition or differentiation as the rock solidified. Zones of lighter colored, more acid facies may be found in the center or margins of the sills or anywhere through the mass as schlieren-like streaks. No definite evidence of stratification, that is, arrangement according to mineral density, within the sills could be found, but differentiation due to crystallization and changing composition of the magma is suggested by the occurrence of seams, dikes, lenses, or apophyses of lighter colored types (aplites, pegmatites, and quartz veins) within the main mass of the sills. Most of these changes are best recognized microscopically and by this means a complete series of rock types, ranging from quartz-gabbro to quartz vein may be found, though the main mass is predominantly that of a quartz-rich diorite or quartz tonalite.

The rock types are all unusual. They contain abnormal amounts of quartz, for in most of them the quartz exceeds the feldspar in abundance, even where more than 60 per cent of the minerals are dark. This abnormality of the magma is peculiar to the sills of the entire region wherever they have been studied. Both Daly and Schofield mention the presence of never-failing but variable amounts of
quartz in the gabbros in the Purcell Mountains and Pardee describes interstitial quartz in the diabase composing the Wishards sill in the St. Joe region. In neither of these localities, however, does the quartz appear as abundant as in the Clark Fork district, a feature that is reflected perhaps in the more acid character of the varieties here as compared with the dominantly gabbroic kinds of the neighboring regions.

LITHOLOGY

In all the rock types hornblende, with a peculiar and distinctive pleochroism (x=yellowish green color, y=greenish, z=greenish blue) is the most interesting of the minerals. In some sections the hornblende contains cores of hypersthene or augite, and it is probable that the hornblende has in every case altered from the pyroxene. Biotite accompanies the hornblende in most of the­sils and in some it is in excess. The biotite is usually the titaniferous variety. Of the light minerals, quartz predominates. The feldspars are several in number, including zoned, finely twinned and untwinned plagioclase within the range of andesine, and in some few rocks microcline and orthoclase in addition. With the less abundant minerals and accessories may be listed augite, hypersthene, rutile, ilmenite, pyrite, pyrrhotite, apatite and zircon (rarely), and such secondary products as chlorite, zoisite, kaolin, epidote, and sericite (?). Most of the secondary products are probably the result of hydrothermal alteration and not surface weathering.

In the rocks with normal textures the hornblende and biotite have crystallized first and preserve their crystal outline against the quartz and feldspar, except that the hornblende fails to show good terminal planes. The plagioclase, usually clouded with secondary products, shows crowding or mutual interference during crystallization, and hence has imperfect crystal outline. The quartz occurs as interlocking grains, cementing the other minerals. These usual relations are illustrated on Plate V, A. Orthoclase, where present, shows crystallization ahead of the quartz but later than the plagioclase. Microcline where present is the last to complete its growth and shows replacement of the earlier minerals, including the quartz.

Most of the rocks have, however, very interesting textural relationships between the quartz and plagioclase in the nature of peculiar graphic intergrowths as illustrated on Plate V, B. In these the quartz forms the host and there has apparently been no definite scheme in the ratio of the quantity of the two minerals such as occurs in the normal
micrographic granite in which the feldspar forms the host mineral. In
many of these intergrowths the polysynthetic twinning of the plagioclase
is preserved. It is possible that much of the quartz in these
unusual intergrowths is deuteric or introduced later through hydro-
thermal agencies.

As a result of detailed microscopic studies of these sills, a large
number of rock varieties may be recognized. The prevailing kind is
- a quartz-rich diorite (composed of andesine, quartz, and a dark mineral)
generally a hornblende-bearing variety, but from which a biotite
variety must be distinguished. Rocks more basic than diorite are rare
in the district, although quartz-gabbro (composed of hornblende, labra-
dorite, and quartz) is common to the north. Other more acid facies
(shown by increase in orthoclase and microcline) are more or less
common to many of the sills, and these usually include granodiorite,
and, in one sill, granite, both with an unusually high percentage of
quartz. Narrow seams of aplite (fine grained rock composed of quartz,
andesine, with very little dark mineral) are numerous in most of the
sills, and are distinguished mainly by their light color against the
darker color of the main sill rock. Pegmatite is less abundant than
the aplite, from which it is distinguished by its coarser and graphic
texture. Both show close mineralogical relationships to their parent
rock. Along with the pegmatites and aplites must be included the
quartz veins, which are more numerous than either and which in the
district to the north carry sulphides. Some of the aplites merge with
quartz veins.

JURASSIC (?) SYSTEM

Two periods1 of batholithic invasions are recorded in the state: one
at the close of the Jurassic, when the Idaho batholith and its out-
liers were intruded, and the second in late Miocene or in Pliocene time.
All the batholithic rocks of this district form a partly exposed mass
which is a continuation of the Nelson batholith of Canada of Jurassic
age and contemporaneous with the Idaho batholith. The eroded sur-
face of the same batholithic mass south of Pend Oreille Lake is covered
by Columbia basalt of Miocene age. This makes an assignment in age
younger than the Miocene impossible. The batholithic intrusions of
the district closely followed the Cordilleran Revolution, during which
the rocks were folded and faulted by mountain building forces. The
igneous magma was injected or made its way into the newly broken
rock and cooled as batholiths, stocks, and dikes.

1 Ross, Clyde P., op. cit., pp. 473-484.
The main batholith lies to the west of the Purcell Trench in the Selkirk Range and is represented in form and outline by the range. This batholith covers more than a thousand square miles, extending northward to the international boundary and southward for more than fifty miles. Another smaller batholith, but covering more than forty square miles, lies on the west slope of the Cabinet Mountains and outlines the topographic depression between the divide and the Purcell Trench. It also extends into Boundary County and may cover more than a hundred square miles. Part of the body crosses Pack River near its mouth and reaches Pend Oreille Lake.

Several smaller bodies or stocks lie in the Cabinet Range: one at the head of Lightning Creek, another nearer its mouth and not far north of the Hope fault. Another lies along North Callahan Creek; and another a few miles to the southeast near the Montana line. Many smaller stocks and dikes also occur in the district, but, instead of being dominantly granitic in texture as in the larger masses, are fine grained to dense and extremely porphyritic, and must therefore be classed as porphyries. They occur in a fringe or border zone about the larger stocks and batholiths, and are especially numerous in the Purcell Trench and in the Cabinet Range between Pack River and Hope, where they range from a few feet to a few hundred feet in thickness. In composition, they are similar to the larger granular masses, but they have been subjected to two rates of cooling, which has resulted in two stages of crystal growth and size.

Lamprophyre dikes of dark color and of composition different than the porphyries just described are also abundant in the area, especially about the margins of the stocks and batholiths, as well as within these masses. These usually form dikes a few feet wide and are frequently found in association with veins, especially as disclosed in underground workings. They are later in their intrusion than the other rocks, though genetically related to them, and in this district were given off in the latest stages of igneous activity, barely preceding the mineralization, and probably in part overlapping. For this reason, they are of more than ordinary importance and interest.

Acid differentiates represented by pegmatites are also abundant in some parts of the area. These may be regarded as complementary to lamprophyres.

**COMPOSITION OF INTRUSIVES**

The prevailing rock of the larger stocks and batholiths is granodiorite, which maintains a remarkably uniform composition throughout
most of the region, except for local areas where some of the rock has quartz monzonitic affinities. The porphyry dikes are classed mainly as granodiorite porphyries, although a few are quartz monzonite-porphyries. Pegmatites are numerous as dikes and seams near the margins of some of the granodiorite batholiths or stocks, but are completely lacking about others. Genetically, these are related to the intrusion of granodiorite and represent the concentrations of aqueous solutions that were given off after the main mass of the magma had solidified. They serve as an intermediate link between the granodiorite and quartz veins. The lamprophyres are basic rocks of wholly different composition and show little relation to the granodiorite. They are basic differentiates given off from greater depths after the main mass of the magma had solidified, and are approximately contemporaneous with pegmatites and mineral veins. A large variety of lamprophyres occurs in the district.

For convenience, the different rocks will be described in the following order: granodiorite, granodiorite porphyry, pegmatite, and lamprophyre.

**GRANODIORITE**

The granodiorites of this region have a composition remarkably close to that of the even grained type of rock of California, but they differ from it in their outstanding coarsely porphyritic texture, which is well developed in much of the Selkirk Range, particularly near Dover and Laledoe; on the west slope of the Cabinet Range except its southern extremity near Pack River and Lake Pend Oreille; and in most of the stocks, except that near the Hope fault on Lightning Creek. Phenocrysts of pinkish and white microcline up to two inches long are very common, and some attain lengths of six and even eight inches. These phenocrysts are embedded in a groundmass of medium to coarse-grain, like the mass of an ordinary granite, as illustrated in Plate VI, A. In most parts the phenocrysts are scattered and are only in sufficient abundance to prevent the rock from being classed as a quartz diorite, but in some places the phenocrysts are so abundant that the rock is more properly classed as quartz monzonite.

The phenocrysts apparently show no regular arrangement or orientation within the rock but occur at random. The texture of the main rock mass, excluding the phenocrysts, is granular or granite. Only along the east margin of the Selkirk batholith north of Sandpoint does the rock show a faint gneissic banding, probably due to movement of the magma during cooling stages. This part also shows a notable lack of phenocrysts.
A. PORPHYRITIC GRANODIORITE
Much of the granite of this region is porphyritic with phenocrysts of microcline ranging up to eight inches long.

B. LAMPROPHYRE "CONGLOMERATE" DIKE
Details in the dike showing thin blocks of granite from the wall partially replaced by the lamprophyric matrix.
The granodiorite has a light gray color, parts of it nearly a brilliant white, others slightly pinkish. The unaltered rock consists of plagioclase (zoned but within the range of andesine), quartz, microcline, hornblende, and biotite, and contains very subordinate amounts of the following accessory minerals: magnetite and ilmenite, zircon, apatite, rutile, allanite, and titanite. The texture of the rock is shown by the following sequence of crystallization: (1) hornblende and biotite, which normally have good crystal form; (2) plagioclase, which takes the space left by the hornblende or biotite and shows mutual interference of growing crystals; (3) quartz, which cements the earlier formed minerals; (4) microcline, which is interstitial among all the other minerals. The granodiorites occurring in the Selkirk Range have been fully described by Gillson in an article entitled "Granodiorites of the Pend Oreille district of northern Idaho," and his description, except for the occurrence of the microcline phenocrysts, fits most of the rocks of the Clark Fork district as well.

Most of the granodiorite contains nearly equal quantities of hornblende and biotite, but the stock near Lake Darling at the head of Lightning Creek and the greater part of the batholith on the west slope of the Cabinet Range, has hornblende to the exclusion of biotite. These rocks are more calcic or basic than most of the other granodiorites in the district. On the other hand, some stocks and the southern end of the batholith in the Cabinet Range have biotite nearly to exclusion of hornblende. They are more quartz monzonite in character. The dark minerals comprise about 18 per cent of the rock. They show from partial to nearly complete alteration to epidote or chlorite.

The plagioclase is chalky white, both in hand specimen and in thin section, and most of the crystals are thoroughly altered to a heavy mass of epidote and kaolin, usually with some white mica (sericite?). In some crystals, the twinning and zoning of the plagioclase may still be recognized and indicate a range of composition within that of andesine.

Quartz normally constitutes from 15 to 25 per cent of the rock and is readily recognized in most of the hand specimens. It is unusually abundant in one variety near Oden, where it forms more than half of the rock.

The microcline is of unusual interest in that it occurs both as phenocrysts and in the groundmass. Gillson has shown that the microcline in the non-porphyritic granodiorites is a late introduction into

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the rocks, which has formed by replacement after the rock had solidified. In the Clark Fork district the microcline, both as phenocrysts and in the groundmass, is clearly the latest mineral to complete its crystallization and is always interstitial with respect to other minerals, as well as showing veining and replacement of them. The microcline phenocrysts appear to the unaided eye to have very nearly perfect crystal boundaries, but when their borders are examined in thin section they are minutely irregular and pass around or between the other minerals. Their borders also show penetration and replacement of the other minerals, particularly the quartz and andesine, as illustrated in Plate VII, A. In addition, the phenocrysts hold numerous rounded and embayed inclusions of these minerals, and even patches of the groundmass, as illustrated in the same plate (VII, B). Most of the phenocrysts have apparently grown by assimilating or replacing the already crystalline minerals of the rock. Possibly, pneumatolytic emanations carrying potash from still deeper molten parts of the batholiths soaked upward through the still hot rock and added in optical continuity to the early crystals of microcline, causing them to enlarge as phenocrysts by replacing the minerals which surrounded them. The microcline forms less than 20 per cent of the rock, but always more than 10 per cent.

Titanite and allanite also occur in most of the sections. Their manner of occurrence is striking, the shape and form of the grains indicating that they, too, were not present at the time the rock solidified, but, like the microcline, were formed in the hot, solid rock during the late deuteric phase. In later stages Gillson has shown that the solutions were more nearly hydrothermal and attached the feldspars, altering the plagioclase to epidote, kaolin, and sericite (?), the microcline less extensively to kaolin and sericite, and the hornblende and biotite to epidote and chlorite. In contrast to the prevalence of this deep-seated alteration, most of the granodiorite is very free from weathering effects, owing to tremendous scouring by very recent glaciation.

The main feature of the granodiorites, aside from their petrography, is their bearing on ore deposition and their influence on structure. The study in this district as well as that in the Pend Oreille district has shown a clear connection between igneous processes and ore deposition. Gillson's paper on the granodiorites is of much interest in showing that the after-effects of igneous intrusion modify greatly the rock itself and serves further to bridge the gap between intrusion and ore deposition.
A. PHOTOMICROGRAPH OF THIN SECTION OF GRANODIORITE

Microcline phenocryst (M) with characteristic plagioclase structure irregularly replacing a plagioclase crystal (P) of the groundmass as well as holding some rounded inclusions of quartz. These relations suggest that the phenocrysts have in part grown by replacing other minerals of the rock after the rock was wholly crystalline or nearly so. Crossed nicks.

0.5 mm

B. PHOTOMICROGRAPH OF THIN SECTION OF MICROCLINE PHENOCRYST IN GRANODIORITE

The phenocryst (plangled structure) holds a rounded and embayed remnant of the quartz (Q) and plagioclase (P) groundmass. The partial replacement of the groundmass suggests that the phenocryst developed in part later than most of the other minerals in the rock. Crossed nicks.

0.5 mm
A. PHOTOMICROGRAPH OF THIN SECTION OF GRANODIORITE PORPHYRY
This picture illustrates one of the textures of the groundmass, granophytic intergrowths of quartz and feldspar. Phenocrysts not shown. Crossed nicks.

B. PHOTOMICROGRAPH OF THIN SECTION OF MICROSPHERULITIC GROUNDMASS IN GRANODIORITE PORPHYRY
A common texture of the groundmass of the granodiorite porphyries, microspheulitic intergrowths of quartz and feldspar, due probably to rapid cooling. Crossed nicks.
GRANODIORITE PORPHYRY

The prevailing mineral composition of the porphyries is that of granodiorite porphyry, with the same list of minerals and in about the same proportions as in the normal granodiorite. The only distinctive difference is in texture, which indicates that the granodiorite porphyries, unlike the granodiorites, have two generations of crystals dependent on two rates of cooling. Not only are the phenocrysts in the porphyries more numerous, but the groundmass is finer grained and its minerals are indistinguishable in the hand specimen. The porphyries are in general lighter colored than the granodiorites, some of them appearing nearly white. Several of the dikes are distinctly pink, because of the color of both the feldspar phenocrysts and the groundmass.

The unaltered rock consists of plagioclase (andesine), quartz, orthoclase, hornblende, and biotite, and several accessories that include magnetite, apatite, titanite, rutile, allanite, and zircon. Of these, the andesine and quartz predominate. Normally, the phenocrysts constitute about 50 per cent of the rock and include andesine with multiple twinning, orthoclase, and quartz, one or all of which may be present. Biotite and hornblende perhaps belong to this stage, but both are relatively inconspicuous. Some of the plagioclase and orthoclase phenocrysts are two inches long, but usually they may be compared in size with the crystals of the groundmass of the porphyritic granodiorites. The larger crystals have clear, glassy centers, but their borders are opaque and white. Some of the crystals show rounding or partial resorption. This phenomenon is best typified by the quartz, most of which occurs in rounded, embayed grains from one quarter to one half inch in diameter. Much variation occurs in the abundance of phenocrysts and the proportion of quartz, andesine, and orthoclase, so that it is difficult to describe any rock as typical.

The phenocrysts are usually embedded in a grayish, or, less commonly, pinkish groundmass whose minerals cannot be distinguished in the hand specimen, and only with difficulty, if at all, in thin section. In some rocks the groundmass is finely microcrystalline granular and is composed of andesine, quartz, orthoclase, and several accessories; but in other rocks the crystals are so minute that they are not easily differentiated. More commonly, the groundmass is composed largely of radiating granophyric or microspherulitic intergrowths of quartz and orthoclase, or quartz and plagioclase, as illustrated in Plate VIII.

The granodiorite porphyries show the same kind of alteration as do the granodiorites, except that the degree of alteration is much
greater. This difference is no doubt due to the fact that the porphyries crystallized ahead of the main bodies of granodiorite and were subjected to greater quantities of the batholithic emanations during a longer time. Titanite and allanite are relatively more abundant in the porphyries than in the granodiorites. The feldspars are especially altered, and except for some of the largest phenocrysts, which retain glassy centers, are almost wholly changed to kaolin and sericite (7). The biotite and hornblende also show extensive alteration and most of them are represented by areas of greenish chlorite and epidote.

The granodiorite porphyries are most numerous in the southern part of the district in the low hills of the Purcell Trench and on the southwest slope of the Cabinet Range between the Trench and Hope. These bodies all lie north of the Hope fault. The location of some of the larger bodies is perhaps related to structural features such as faults developed during the general crustal disturbance that preceded and accompanied the batholithic intrusions. Many of the smaller porphyry dikes are really apophyses from the granodiorite and show a great irregularity of form, which suggests evidence of magmatic stopping as outlined by Daly1 in the ranges to the north. In several places the porphyry dikes have been cut off or intruded by the granodiorite, which indicates their older age, but in other places the porphyry merges with the granodiorite, proving that they are products of but one general period of intrusion, of which the porphyry dikes represent the oldest. Only two porphyry dikes were found which cut the granodiorite, and these were near the margin of the batholith in the Cabinet Range. The dikes, about two feet wide, were probably given off from deeper sources after cracks had occurred in the outer crystalline shell of the batholith.

Only a few of the larger bodies of porphyry were mapped. The largest of these underlies the southern part of the low group of hills north of Kootenai in the Purcell Trench. The stock is about a mile and one-half long and one mile wide on the surface. It has numerous grit-like quartz phenocrysts in addition to large crystals of plagioclase. This body also has biotite and hornblende, and merges with normal granodiorite. Other dikes and stocks of smaller size, though some of them are large enough to be mapped, outcrop on the hill south of Culver in the hills cut off from the Cabinet Range by Pack River, and on the south slope of the mountain to Hope. The dikes on the hill near Culver are similar to those near Kootenai, but contain a few orthoclase phenocrysts in addition to quartz and andesine, and biotite predominates over hornblende. Many dikes from 10 feet to 300 feet

wide may be examined in the highway cuts between Pack River and Hope. Many of them are like those mentioned above, but some are without phenocrysts of notable size and their porphyritic character is best determined in thin section under the microscope.

PEGMATITE

Pegmatites are numerous near the margins of some of the granodiorite batholiths and stocks, both in the upper shell of the batholiths and in the bordering sedimentary rocks, but they are wholly lacking about others. The complete lack of pegmatite in the Cabinet Range south of Grouse Creek is noteworthy. This is in marked contrast with the Elmira region to the north where pegmatites are especially abundant. They are also numerous in some parts of the batholith which forms the Selkirk Range.

Most of the pegmatites occur as small seams or lenses along the bedding planes of the metamorphosed sediments, and as irregular masses within the granodiorites. In some parts of the Elmira region, the sedimentary rocks are thoroughly impregnated with pegmatite for several hundred feet from the contact with the batholith, and it is difficult to decide whether the formation should be mapped as igneous or as sedimentary. Similar relationships were observed in some parts of the Selkirk Range, but the pegmatites in general are not as numerous. In some parts of the batholiths, the pegmatite appears to merge with the granodiorite, but usually it occurs as bands with distinct walls. Only one large body of pegmatite was found, a dike several dozen feet wide and more than two miles long outcropping between Sand Creek and Grouse Creek southeast of Elmira.

The pegmatites usually have the texture of coarse grained granites, with the feldspar crystals measuring two or three inches long and less, but may have in addition the typical graphic or pegmatitic texture, where the feldspar encloses minor amounts of quartz in hieroglyphic pattern. Most of the seams and dikes are uniform throughout except for slight differences in size of minerals, but a few have central segregations or cores of pure quartz. One often sees coarse-grained granite with flakes of muscovite one to two inches in diameter scattered through it. The leading minerals of the pegmatites are feldspar (microcline), quartz, and muscovite. Minor minerals and accessories are oligoclase, and garnet, each of which is of variable importance. The plagioclase, if present, is clouded with kaolin and sericite (?), but the microcline is fresh.
The occurrence of the pegmatites about certain parts of the batholiths is probably explained by the character or "wetness" of the granodiorite magma. In those parts where hornblende is the dominant dark mineral, the batholiths are generally without pegmatites, but in those parts where biotite and a more acid character of the magma is indicated the pegmatites appear. The batholith near Elmira, which shows the greatest number of pegmatites, has quartz monzonitic affinities and part of it is without either biotite or hornblende. The presence of pegmatites has had a profound influence on the metamorphism of the sedimentary rock, for in those areas where pegmatites are lacking the metamorphism is scarcely noticeable, whereas in those areas with numerous pegmatites the sediments have been converted to mica schists and to gneisses.

**Lamprophyre**

Lamprophyric rocks are particularly numerous in the Clark Fork district, especially in those parts of the region that show the greatest structural disturbance, such as the border zone of the great Hope fault. Here the lamprophyres occur as dikes filling fissures much the same as do mineral veins and several occupy the same fissure with veins. These rocks are far more numerous in association with mineral veins than elsewhere, and for this reason are of considerable importance in the economic studies of the district. Many dikes are also found in the Cabinet range and Purcell Trench in both the sedimentary rocks and in the bodies of granodiorite. A great number as well as a large variety are exposed along the highway between Pack River and the town of Hope north of the Hope fault. They are perhaps equally abundant on the south side, but the dense vegetation and heavy mantle of drift in the lower country more effectively hides them.

Most of the lamprophyres occur in dikes from 10 to 30 feet wide, cutting the bedding of the sedimentary formation. A few are as narrow as one foot. Several attain great size and are more properly classed as stocks than as dikes. Two of them are sufficiently large to be mapped. Several of the dikes exposed along the highway between Hope and Pack River have nearly flat roofs as much as 150 feet wide, and resemble small stocks. One dike of unusual appearance, which might be classed as a "conglomerate" dike, occurs in the granodiorite about three miles southeast of Elmira. During the intrusion of this dike, chunks or fragments of the granodiorite wall were torn loose and caught up in the lamprophyric magma which bleached some of the fragments and rounded all of them by replacement so that they appear as light colored
boulders in a dark, fine grained matrix. Some of the boulders are ten inches and more in diameter (Plate VI, B). Another dike or small stock shows unusual features, for it merges with a porphyry dike on the hill east of Kootenai and has numerous rounded "porphyry" crystals. These occurrences are very uncommon, for most dikes have sharp walls and are without inclusions.

The lamprophyres are different from any other igneous rock in the district. They contain distinguishable crystals of dark minerals set in an extremely fine grained matrix. The chief characteristic of lamprophyres is that they are dark colored and porphyritic, with the phenocrysts composed of dark minerals. These minerals, in the Clark Fork district, are generally well-formed, slender prisms of hornblende or augite from one-quarter to one inch long, and tablets of biotite, with either the biotite or the hornblende (or augite) predominating in any single type, and are embedded in a gray to grayish black groundmass which is greenish to brown where weathered. The groundmass is composed of feldspar and small crystals of the dark minerals, and has a texture that ranges from cryptocrystalline granular, often irresolvable because of excessive alteration, to coarser textures like that of a fine to medium grained granite. A few dikes of lamprophyre are not conspicuously porphyritic and are finely granular like some granites.

The color of the rock depends on the proportion of the light minerals to dark, and in most varieties the two occur in nearly equal amount. A few are unusual in that the light minerals predominate, for normally the lamprophyre is characterized by having the dark in excess. The lamprophyres differ from the more common moderately basic rocks, such as quartz diorite, diorite, and some gabbros, not only in the character of the phenocrysts, but also in their high content of alkalies and water, which are important constituents of ore-forming solutions.

The biotite in the lamprophyres usually occurs as black, scattered, shining, pseudo-hexagonal plates, that in thin section has a beautiful pale brown to deep reddish brown or reddish black pleochroism, unlike that of the biotite in any other igneous rock. The hornblende, which may or may not accompany the biotite, is black in the hand specimen, but in thin section is brownish and usually does not exhibit greenish tones. The augite which occurs with hornblende in some of the dikes is coal-black in the hand specimen, but colorless in thin section. Olivine in large rounded grains is present in many of the dikes as phenocrysts, in addition to biotite or hornblende, but it is wholly altered to serpentine with heavy zones of magnetite on the borders, or in the centers, or along cleavage cracks. The feldspars of the groundmass are either
plagioclase or orthoclase, both of which show variable degrees of alteration to kaolin or sericite (?) or to both. The feldspars are invariably accompanied by minor quantities of quartz. Alteration products are numerous, for the lamprophyres weather more rapidly than any other rock in the district. Fortunately the recent glaciation has made fresh rock easy to obtain.

This district contains nearly every known variety of lamprophyre that is at all common, and is represented by minette, kersantite, vogesite, spessartite, and odinite, as well as several intermediate types between those rich in plagioclase and those rich in orthoclase on the one hand, and biotite-bearing varieties and hornblende or augite-bearing varieties on the other. The relationships of the several varieties are made clear in the following table:

<table>
<thead>
<tr>
<th>Biotite Dominant</th>
<th>Acid Plagioclase Dominant</th>
<th>Basic Plagioclase Dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minette</td>
<td>Kersantite</td>
<td>Labradorite</td>
</tr>
<tr>
<td>Vogesite</td>
<td>Spessartite</td>
<td>Odinite</td>
</tr>
</tbody>
</table>

The varieties are best identified microscopically, as the feldspars are impossible to recognize in any other way.

Lamprophyre dikes are also common in the Coeur d'Alene district. In both places, several varieties of lamprophyres are found, but, in each those having phenocrysts of biotite predominating. In the Pend Oreille district, the feldspar of the groundmass is prevailing plagioclase and the rock is, therefore, strictly classified as kersantite, whereas in the Coeur d'Alene district the feldspar in nearly every dike is orthoclase and the rock is minette. In contrast, the Clark Fork district has the characteristic type of both districts, and, in addition, has the kinds in which hornblende predominates as phenocrysts, as well as in the groundmass. Of the many rocks studied, most have the composition of spessartite, a hornblende or augite, plagioclase rock, usually with a little olivine. The odinite, similar to the spessartites, but with more basic plagioclase, occurs once; the others occur several times.

The intrusion of lamprophyre dikes is a common sequel to the intrusion of granitic rocks and such dikes are regarded as basic differentiates that have come up from a deep-seated source after the upper

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part of the granitic magma has solidified. In the Pend Oreille district, their intrusion was essentially contemporaneous with that of the ore deposition, for many of the ore bodies are cut by lamprophyric dikes, but the association of the ore is so nearly contemporaneous that though the ore preceded the dikes, hydrothermal alteration associated with the ore-forming solutions followed dike intrusion.\(^1\) In the Clark Fork district, on the other hand, those lamprophyres that have been encountered in mine openings as a rule are cut by the veins, and their time of intrusion, therefore, mainly preceded that of mineralization.

**STRUCTURE**

**GENERAL FEATURES**

Faulting is the most outstanding structural feature of the Clark Fork district. Many of the faults are clearly associated with igneous intrusion, some being formed entirely by forces which initiated the intrusions, and others continuing to be active after the intrusive rocks had solidified. Those which were formed by forces of intrusion are represented by a mosaic pattern of fault blocks in the sedimentary rocks about the margins of the larger stocks and batholiths. Some of the faults have displacements of thousands of feet, largely in a vertical direction. The faults that continued to be active after the intrusive rocks had solidified have the greatest magnitude, and length. At least one of these continued to be active for a longer period than the others, and because it trends in a nearly westerly direction offsets the others, which trend north. This fault, the Hope, is very similar to the Osburn fault of the Coeur d'Alene district, and like the latter, shows pronounced mineralization along its course, particularly in those areas where minor faults related to igneous intrusion have also served to break or shatter the rock and provide additional openings for the passage of mineral-bearing solutions given off by the magma at greater depth. Movement along the fault was probably active both before and long after mineralization.

The folding in the region is distinctly older than the faulting, although both are probably related to the same orogenic forces. A large open syncline in the sedimentary beds has been cut in two and offset by the Hope fault. The fold has been disturbed by other great faults, and locally by the fault mosaic about the stocks and batholiths.

FOLDING

The strata have been inclined from the once horizontal position to angles ranging from eight degrees to vertical. Away from the borders of the batholithic masses, the folds have gentle to moderate dips, completed before the intrusions. The greater part of the Cabinet Range in north Idaho is carved from the broad west limb of a gentle syncline whose axis lies somewhere in Montana. From north of Hope the beds dip eastward with an average inclination of 80° for at least ten miles across the strike. On Goat Mountain the dip flattens to about 15°, but on Scotchman Peak increases again to 20°. The beds are locally disturbed about areas of igneous rock, especially the stock on Lightning Creek just north of the Hope fault, and about the borders of other stocks and batholiths of the Range. The strike of the beds is generally about N. 30° E., but a steepening of the beds in the northern part of the district has changed the direction near the Montana line to N. 20° E. The syncline has been cut off on the north by faults which lie outside the district, and also on the south by the Hope fault.

The synclinal structure is continued on the south side of the Hope fault, but the two parts do not match, because subsequent movement along the fault has displaced the beds horizontally. On the peninsula south of Hope the beds dip about 60° eastward and their dip diminishes more or less gradually to 8° near the Montana line. A large fault along Johnson Creek in the Coeur d'Alene Mountains has modified this structure, but has not destroyed it. East of this large fault the beds have been little disturbed by faulting and everywhere the dip is eastward. The axis of the syncline lies about two miles east of the state line. The beds strike more nearly north and south than they do in the Cabinet Mountains, and their average strike is about N. 10° E. The southern part of the syncline is peculiarly singular in that it plunges northward against the Hope fault, a character that is perhaps related to vertical movement along that great fracture.

FAULTING

For convenience the faults of the district will be described as intrusion faults and as post-intrusion faults, a scheme used by Sampson in classifying the faults in the adjacent Pend Oreille district. The intrusion faults are more or less readily identified about the margins of the batholiths, where they invariably stop against the igneous rock. The post-intrusion faults are less easy to recognize, for some of them undoubtedly began as intrusion faults and continued active until a

much later time. It is probable that the Hope fault, which is recognized as the youngest of the post-intrusion faults, came into existence during the general folding of the region and continued as a zone of movement long after igneous intrusion. It should perhaps be separated from the other great post-intrusion faults which trend in a northerly direction, nearly at right angles to it, and which probably are the result of forces only distantly related to those that caused the Hope fault. For want of a more suitable classification, however, the Hope is described as a post-intrusion fault.

**Intrusion Faults**

The term “intrusion fault” applies to faults brought about by the intrusion of the magma. Such faults occur on a grand scale in the Pend Oreille district, where some of them have apparent displacements of from 4,000 to 10,000 feet. The courses of individual faults are very straight, their dips generally vertical, and their general pattern is of the block type. These faults extend in more different directions than the post-intrusion faults. This type of faulting occurs along the Purcell Trench in the Clark Fork district and about the batholith in the Cabinet Range. Several great faults in the Cabinet Range east of Elmira are probably of this class, for in no other way can the great discrepancies in dip and strike of the beds on opposite sides of the fault planes be explained. The reason for assigning the igneous magma as a causative action in the formation of these faults and not regarding the faults as being merely older and having no connection with igneous intrusion, is that these faults are found only about stocks of igneous rocks. The fault mosaic in the Purcell Trench is probably in large part caused by the intrusion of the Selkirk batholith, and the Trench, itself, is probably the result of easy erosion along this greatly shattered zone, which was further broken by post-intrusion faulting. This structure also continues beneath Pend Oreille Lake, as inferred from the distribution of the beds on the three islands south of Hope.

The intrusion faults are probably of economic significance, especially the smaller ones that occur about the tops of the intrusive stocks, for many with small displacements are mineralized. The mineralization near the town of Clark Fork is in an area of shattered rocks, similar to that in the Purcell Trench, but on a much smaller scale, and the relationships here suggest the presence of an underlying intrusive stock not yet exposed by erosion. Had time been available for accurate mapping of the structure in the mineralized belt, the map would show

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the pattern of a fault mosaic. In this area the mineralization is mainly along steep-angled thrust faults, such as would have been developed by the lifting force of an intrusive magma. Movement is recorded along the fissures during and following mineralization, and this movement might be inferred as due to readjustments within such an underlying magma.

POST-INTRUSION FAULTS

The post-intrusion faults are on a much grander scale than the intrusion faults and are of great displacement and length. These faults have a marked topographic expression where they have been recognized, usually with valleys carved along them, or by a series of saddles where they cross ridges. Their age with respect to the intrusion of the granodiorite magma in the Pend Oreille district was determined by Sampson by the complete lack of strong contact metamorphism in the sedimentary rocks faulted against the granodiorite. This conclusion is verified further in the Clark Fork district by the character of the ore deposits on the opposite sides of the fault planes, where deposits which were formed at characteristically moderate temperatures and probably moderate pressures have been brought alongside those formed at the higher temperatures prevailing at considerably greater depths. The displacement of plateau surfaces as along the Hope fault also offers additional information as to the age of these faults or at least their later movements. The greatest movement along all of these faults probably occurred before mineralization, but in some cases considerable movement took place later.

The largest post-intrusion faults are the Packsaddle, which is one of the dominant structures in the Pend Oreille district; the Purcell fault; and the great Hope fault. The Packsaddle fault and the Purcell fault have a northerly trend, and both stop against or have been offset by the Hope fault, which crosses the district from east to west. The Hope fault may be classed as a great transverse fault. The northerly trending faults may perhaps be related to relaxational strains following the folding and batholithic intrusions, but the Hope fault may be in large part the result of greater structural adjustments which lie entirely outside the area; perhaps, in some way, as an adjustment to the great overtrusts of the Rocky mountains to the east.

PACKSADDLE FAULT

The Packsaddle fault was named and described by Sampson, who traced it for 18 miles along the eastern side of the Pend Oreille dis-
trict, past the east base of Packsaddle Mountain, and suggested that the main branch might continue down the remarkably straight course of Johnson Creek to the Clark Fork Valley, and join the fault across Howe Mountain, mapped by Calkins. As Sampson suggested, the fault is easily recognized along the valley of Johnson Creek and accounts for the remarkably straight course of that stream. A saddle marks its expression across Howe Mountain, and it ends against a branch of the Hope fault.

The fault has a general trend of about N. 25° E. and is probably normal with downthrow to the west as determined by Sampson’s investigations farther south. Its relationship is not wholly clear in the field, as the fault plane was not seen underground, but minor faults nearby indicate that its dip is probably westward at a steep angle. On Howe Mountain the beds of the lower Wallace are alongside the beds of the upper Wallace, involving a stratigraphic throw of about 4,000 feet. As the fault cuts the strike of the tilted beds at an angle, the apparent displacement increases southward, and near the mouth of Johnson Creek the Wallace is alongside the upper St. Regis, involving a throw of 7,000 to 8,000 feet. About a mile and a half above the valley’s mouth a normal fault striking northeast stops against the Packsaddle fault and has brought Striped Peak beds against the Wallace, as well as along the St. Regis, which involves a much greater displacement along the fault plane. The beds to the west of the Packsaddle fault have a steeper dip than those on the east side, this difference amounting to as much as ten degrees. This difference increases northward along the fault.

The structure on opposite sides of the Packsaddle fault is very different. To the east lies a large area consisting of Wallace and Striped Peak formations of simple structure, but to the west lies an area of complicated structure that is wonderfully displayed in the Pend Oreille district.

PURCELL FAULT

A great post-intrusion fault is inferred along the Purcell Trench to explain the geologic pattern within that great depression. This inference is based upon the relation of the sedimentary rocks with their minor areas of igneous rocks on the east side of the Trench to the great batholith on the west, which suggests that the rocks on the east have been downfaulted against the main batholith and thus preserved from the erosion that de-roofed the batholith of the Selkirk Range. This

relation is preserved to the north of the region as well and Kirkham and Ellis\(^1\) have shown a great fault along the Kootenai River in the Purell Trench in Boundary County. The displacement that involves the dropping of the sedimentary rocks with the upper parts of the stocks and batholiths against the main mass of the batholith probably amounts to 4,000 or 5,000 feet. The downthrow is to the east. Because the post-intrusion faulting was along a zone of intrusion faults, the additional shattering of the rocks provided the path for easy subsequent erosion and has controlled the location of the Purell Trench.

This fault, unlike the Packsaddle fault, trends nearly north and south. It probably has several branches within the Trench, where it widens east of Sandpoint. The main fault is very likely a continuation of the Pend Oreille fault, which Sampson has inferred as passing along the southern arm of the lake and northward west of Grouse Mountain to the west arm, where such a fault has been mapped by Calkins. The continuation in the Clark Fork district has apparently been offset to the east for several miles by the Hope fault, which is believed to follow the west arm of the lake.

The presence of the Sandpoint conglomerate suggests earlier diastrophism, probably with faulting, but the nature of this movement cannot be determined in this district. Any pre-intrusion faults whatever in the Purell Trench have been entirely masked by the intrusions and post-intrusion faults.

**HOPE FAULT**

The Hope fault is one of a series of great transverse faults which trend in a westerly direction or a little north of west, and whose displacement, in place of being in a vertical direction as those of the post-intrusion faults mentioned above, is largely horizontal. This kind of fault controls the structure of the Coeur d'Alene district as well as that of the St. Marys district\(^2\) farther to the south, and is a link that helps bind the structural geology of the Clark Fork district more closely with that of the Coeur d'Alenes.

The course of the Hope fault is marked by the strong topographic depression that separates the line of hills between the Clark Fork and the main Cabinet Range. The fracture has been traced from Heron, Montana, to Hope, Idaho, where it passes into the northern arm of Pend Oreille Lake. Its fullest extent has not been determined, but it probably extends for greater distances both to the east and the west.

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\(^1\) Op. cit., Plate I (map).
The fault has not been crossed in any of the mines or prospects and nothing can be learned of its characteristics underground. A nearly parallel fault, which probably represents movement taken up along another plane, has been exposed along a roadway on the west slope of Howe Mountain. The disturbed zone is about a hundred yards wide and has a wide gouge zone. A prospect on what is probably the same fault farther east has passed through more than 60 feet of gouge. These factors indicate a displacement of great magnitude, which is further verified from the stratigraphic relations of the beds on either side of the fault zone. The trace of the main Hope fault is outlined by a distinct depression several hundred yards across, except where completely filled by glacial debris, and it is probably best to consider the fault a complex fracture with many planes of movement distributed through a wide zone. The steep slope of the Cabinet Range suggests that the fault plane dips to the south at a steep angle. The dips of subsidiary fissures on both sides of the Hope fault also show downthrow on the south and angles near 60° to 70°, and, like the majority of the minor fissures, the Hope fault is probably normal with steep dip to the southwest.

The rocks on the north side of the fault belong mainly to the Prichard formation and on the south to the Striped Peak and Wallace formations, a displacement that has brought the top of the Belt series against the lower part. Near the Montana line, the eastward tilt of the beds has brought the Burke into position on the north side of the fault alongside the Striped Peak on the south. It has also brought the Burke and St. Regis on the peninsula south of Hope against the middle Prichard on the north. South of Scotchman Peak the top of the Prichard is alongside the Striped Peak, which involves a vertical stratigraphic displacement of not less than 18,000 feet. Farther west the Wallace formation lies against the middle Prichard, which involves a displacement of more than 20,000 feet.

The magnitude of the displacement measured vertically is difficult to comprehend when the problem of disposal of 20,000 feet of strata at lower depths is considered. However, when other facts are brought in, it is found impossible to match or fit the opposite sides of the fault together into anything like a regular arrangement. The synclines on the opposite sides of the fault do not match, but one is offset several miles with respect to the other. Nor can the northerly trending faults be made to join, but these are also offset by the Hope fault. These relationships suggest that the Hope fault is like the Osburn fault of the

Coeur d'Alene district, to which Umpleby has assigned a pronounced horizontal movement involving 10 to 14 miles. The relations in the Clark Fork district infer that the beds were tilted or folded before movement along the Hope fault occurred. A horizontal movement of from 10 to 14 miles without any vertical movement can explain the apparent great vertical displacement by reason of the original tilt of the beds. However, that there has been considerable vertical movement as well as horizontal may be safely inferred from the displacement of plateau levels on opposite sides of the fault zone and the actual horizontal movement may have been much less than 10 miles.

Movement along the Hope fault probably followed closely on the folding of the rocks of the region and was probably active during igneous intrusion and later. That it did not accompany the folding is probably because the fault plane cuts the folded or tilted beds. That much movement had occurred prior to and during the igneous intrusion is verified by the localization of the great number of lamprophyric and porphyry dikes in subordinate fissures along the present fault zone. Mineral deposition in the subordinate fissures was interrupted several times by renewed movement, which suggests that the Hope fault continued active during that time also and later, for the veins show post-mineral movement as well. Mineralization is believed to have taken place during a late magmatic stage. The relation of the ore bodies on the north side of the fault and those on the south side also suggests considerable movement, possibly largely vertical, after mineral deposition had ceased, for the ore deposits on the south side are those formed at moderate temperatures and those on the north side at high temperatures. This suggests that the tops of the veins have been downfaulted alongside their lower parts. The movement along the Hope fault probably continued in early Tertiary time, for after the region was penepalined in the Cretaceous, the land was re-elevated and the old erosion surface displaced so that it is approximately 1,500 feet higher on the north side of the fault at present than on the south side.

The origin and history of the Hope fault is probably similar to that of the Osburn, with which it probably developed concurrently. Umpleby considers that the great movement along the Osburn fault has been taken up by gliding on a molten subsurface zone and he has shown that the faulting, the mineralization, and igneous intrusion are closely related in point of time. The origin of these great faults is not definitely known, but the cause is probably outside the districts and the faults are probably related to still greater structural features,

which, as Umpleby suggests, may be the great overthrusts in the Rocky Mountain system to the east.

SUMMARY OF GEOLOGIC HISTORY

SEDIMENTARY RECORD

The geologic record begins with the deposition of a great thickness of sediments in a vast shallow sea probably throughout the whole of Algonkian time. These sediments are characterized by fineness of grain, by abundance of ripple marks and sun cracks, by conformable sequence throughout more than 40,000 feet of strata, and by gradual transition from one formation to another. These conditions indicate that the land from which the sediments were derived was of low relief and eroded slowly and that the deposition took place in very shallow water and on vast mud flats frequently exposed to the air. The base of this remarkable series or the floor on which the sediments were deposited has not been brought to view. The accumulation was apparently uninterrupted by mountain building movements nor were there abrupt changes in the conditions of sedimentation throughout this time. These phenomena seem best explained by a great and gradual subsidence which generally kept pace with deposition.

A withdrawal of the seas probably took place at the close of the Algonkian time, but embayment again occurred in the Cambrian, when sandstones, limestones, and shales were deposited with apparent conformity upon the Belt strata. These younger sediments have been preserved from subsequent erosion only near the south end of Pend Oreille Lake, where they have been downfaulted against the older Belt rocks. How long sedimentation continued during the Paleozoic era remains unknown, but the next definite record of sedimentation occurs probably at the close of the Paleozoic when a great thickness of conglomerate was laid down unconformably upon the older rocks. The relation of the conglomerate, deposited under torrential conditions, suggests that orogenic movements occurred at that time, that the land was uplifted, and great valleys were carved which were partially filled with waste from the highlands.

The sedimentary record is then a blank until the middle of the Tertiary, when a thick series of lake beds (Latah formation)\(^1\) was deposited in the valleys, which were carved in the mountains more

deeply than those of today. At that time as much as 1,000 feet of sediments were laid down in the Purcell Trench south of Pend Oreille Lake and were finally covered by Columbia basalt, which has built up the Trench in that part to its present level. This series of lake beds, which was deposited when the lower courses of the valleys were obstructed by the advancing flows of the basalt from the west, probably extended back into the Clark Fork district along the valley of Pend Oreille Lake, along the Clark Fork Valley, and in the Purcell Trench, but subsequent erosion has apparently removed every vestige of these sediments or they are effectively concealed beneath the younger deposits.

The final chapter in the sedimentary record occurs in Quaternary time, when glaciers passed over the district in the Pleistocene and on their retreat left a deposit of glacial till of variable thickness on the mountain slopes and a great thickness of glacio-fluvial outwash and moraines in the valleys. More recently the streams have reworked part of the glacial deposits and have formed flood plains and delta deposits.

**IGNEOUS RECORD**

The earliest record of igneous activity is that which occurred at the close of Algonkian sedimentation or possibly in early Paleozoic time when the vast series of dioritic magma was intruded between the flat-lying bedding planes of the lowest member of the Belt. Their intrusion apparently did not accompany orogenic movement and they caused little disturbance of the invaded rocks.

The next and greatest igneous activity follows closely on the Cordilleran Revolution of late Jurassic when the older rocks were thrown into vast folds and probably faulted under the compressive stresses which were active at that time. The accompanying batholithic intrusions also faulted the invaded rocks, producing a fault mosaic pattern about their borders. Faulting also continued after the borders of the batholiths and stocks had solidified and the long post-intrusion faults of the district were formed, the greatest of these being the Hope. The igneous magma cooled slowly under a thick covering of the sediments as batholiths and stocks of porphyritic granodiorite. These bodies have about their borders a fringe of porphyry dikes and stocks of the same composition which were intruded into the shattered and broken sediments ahead of the main advance of the magma. As the magma cooled, differentiation occurred and numerous aequous solutions were injected into the upper parts of the stocks and batholiths and into the adjacent
sediments in some parts of the area and solidified as pegmatite seams and dikes. More basic differentiates or segregations were given off a little later from deeper parts of the magma, these also cooling as a host of dark lamprophyric dikes in the fractures and fissures in the upper part of the granodiorite bodies and especially in the enclosing sedimentary rock. These were closely followed by aqueous mineral-bearing solutions which deposited mineral veins. In some parts of the region, the veins slightly preceded the lamprophyres, but in all places they are nearly contemporaneous. Juvenile waters given off from the cooling granitic magma caused extensive metamorphism of the sedimentary rocks in some parts of the area around the borders of the stocks and batholiths.

There is no record within the district of igneous activity younger than that of late Mesozoic. A flow of Columbia basalt of Miocene age may be seen near the south end of Pend Oreille Lake. This overlies the Latah formation and it probably at one time extended into the Clark Fork district, but none of it has withstood subsequent erosion.

PHYSGRAPHIC RECORD
EARLY PLANATION AND UPLIFT

The development of the present topographic features goes back to late Jurassic when the sedimentary rocks were folded and invaded by granitic magmas and elevated as a vast mountain system. The mountains at that time were subjected to the agencies of erosion, and by the end of Cretaceous' were reduced to an area of low relief or to a peneplain with here and there residual hills rising as monadnocks above the general level. Erosion at that time cut deep into the rocks and exposed the upper parts of the granodiorite stocks and batholiths. The remnants of this old peneplain are to be seen in the present ridge tops in the general accordance of summit levels that are expressed in all the mountain groups.

The peneplain was then gradually elevated in early Tertiary time, probably synchronous with the Laramide Revolution of late Cretaceous and early Eocene, and intensive erosion again inaugurated, the rivers and stream carving their valleys in the most easily eroded rocks, which were those which had been most extensively shattered by the great faults. At this time the Pureell Trench and the greater Clark Fork Valley probably came into being, their courses controlled by the major zones of faulting. A second less extensive peneplain was carved prob-

ably a thousand feet or so below the earlier as is suggested in other parts\(^1\) of northern Idaho, but this peneplain has been so modified by subsequent erosion by streams and glaciers that it is not clearly recognized in this district. This peneplain was probably completed in Eocene and may explain in part the great width of the two major valleys of the district.

Uplift again occurred and intensive erosion was inaugurated along the earlier lines, so that by Middle Miocene time the land surface was carved much into its present shape, although the relation of the Latah formation in the Purcell Trench to the south suggests that the mountains along the larger valleys were of even greater height than those of today. The uplift of the older peneplains was not everywhere uniform and because of renewed movement along the Hope fault the surface of the peneplain on the north side was raised as much as 1,500 feet above the same surface on the south. Probably by Lower Miocene the streams had reached an old-age stage and had widened their valleys, producing a third peneplain, as is shown by the streams and rivers to the south.\(^2\) The land was then re-elevated and again deeply incised before the drainage was obstructed by the Columbia basalt. These features have also been largely eradicated from the Clark Fork district by the subsequent great glaciation.

The drainage prior to Middle Miocene was probably southward with the Clark Fork having outlet through Pend Oreille, Rathdrum, and Spokane valleys, and joined by Priest River in Rathdrum Valley, which then occupied the now abandoned Hoodoo Valley. Possibly the Koottena River found outlet south through the Purcell Trench and joined the Clark Fork not far from Hope. However, with the damming of the outlet to the west by the advancing flows of basalt and the consequent impounding of water and deposition of lake beds, a lower outlet was probably found northward and the whole drainage was deflected north through the Purcell Trench.\(^3\)

The subsequent history is one of erosion mainly by streams, but also by glaciers, and these agencies have carved the mountains into their present forms and have further widened and steepened the Purcell Trench and the Clark Fork Valley. There is little evidence of uplift since the Miocene and the topography is not essentially changed from what it was then except that it now bears a strong glacial stamp. Many changes in drainage occurred as a result of the glaciation, but these changes will be discussed later as features of glaciation.

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1 Anderson, A. L., op. cit.
Hints of two glacial advances were given in the section on topography and these now need further description.

PLEISTOCENE GLACIATION

The oldest advance of a glacier that has left a record in the district is that of Spokane age, when a sheet of ice of continental proportions, the Cordilleran ice-cap, buried the Selkirk and Cabinet mountains except for a few peaks along their southern margins. The great glacier left boulders or erratics perched upon the peaks in the Lake Darling region at elevations of more than 6,000 feet and also along the southern margin of the Cabinets at elevations somewhat more than 5,000 feet.

The ice deeply scoured the northern edge of the Coeur d'Alene Mountains to elevations of about 5,000 feet, but did not cover the mountains as it did to the north. The direction of the glacial scratches or grooves shows that this great glacier moved southward through the Purcell Trench and Spokane valley and spread out upon the Columbia Plateau.

Little evidence of this glacier remains in the Clark Fork district, for the later advance has obliterated its presence except on the higher ridges and peaks. Southward, however, the glacial lobe left a thick deposit of drift and outwash in the main Purcell Trench, building up its bottom above that of the tributary valleys so that many lakes are now held in the mountain valleys behind gravel dams. For a more detailed treatment of these features, the reader is referred to another paper by the writer.

WISCONSIN ADVANCE

The second and last advance that is recorded in this district was less extensive than the earlier and occupied mainly the Purcell Trench and Clark Fork Valley. The evidence of this lobe is very pronounced, both by the freshness of the scoured bedrock and the freshness of the moraines. A long interval of time existed between this advance and the earlier.

Bretz' has figured the lapse of time since the Spokane glaciation at two and one-quarter times as great as the Wisconsin glaciation, assuming that the strong morainic expression of the latter indicates a late Wisconsin age. This lobe of ice also came from the north along the Purcell Trench, but in the upper part of the Pend Oreille Lake region it divided, one branch continuing southward and

2 Anderson, A. L., Pamphlet No. 18, op. cit.
leaving the terminal moraine at the south end of the lake near Bayview, while the other branch passed up the Clark Fork Valley an undetermined distance. These lobes were fed by smaller valley glaciers from the mountains, one of the most notable of these being the one which sculptured the interesting valley of the West Fork of Blue Creek, where it left a row of hanging valleys. Smaller glaciers lingered in the mountain valleys and about the peaks after the main lobe had retreated, and these have given alpine characteristics to the higher peaks and ridges of the Cabinets and Selkirk mountains, clustering them with glacial cirques, especially on their north sides.

ADJUSTMENTS TO GLACIATION

Any changes in drainage made by the Spokane ice have subsequently been altered by the younger lobe, so that the adjustments herein considered are due to the Wisconsin advance. The most striking of the adjustments is the carving of the valley now occupied by Lake Pend Oreille and its subsequent damming by morainal material. Sampson¹ considers the position and size of this valley to be related to the profound faulting believed to have taken place along it, but that its present form is largely the result of glaciation. Soundings made by him indicate that the floor of the lake is nearly flat and about 1,100 feet below present water level at the deepest place found, between Granite Point and Talache. The reason for the great depth of the lake may be explained, perhaps, by recalling the former depth of the valleys in pre-basalt time when the Purcell Trench south of Pend Oreille Lake was more than 1,000 feet deeper than at present. The subsequent filling of the soft shales and clays of the Latah formation of Middle Miocene age would probably prove to be a small obstacle in the re-excavating and re-shaping of the old valleys by the ice lobes.

The changes of the Clark Fork are also of interest. The ice lobes prevented the Clark Fork from holding its course to the north through the Purcell Trench, where it had probably been deflected by the basalt in Miocene time and the drainage was again established to the south. However, with the retreat of the Wisconsin ice the terminal moraine which holds Pend Oreille Lake in on the south was at such a height that the Clark Fork found a lower outlet by crossing a granite ridge near Dover west of Sandpoint and taking an entirely new course across the Selkirk Range. In doing this it flowed across the valley of Priest River and beheaded it, leaving its lower course, the Hoodoo Valley,

stranded and unoccupied. Further west the Clark Fork stole another
valley and occupied it northward to Metaline Falls, reversing the
direction of flow of the former stream.

Another interesting adjustment is the unique course of Pack River
across the Purcell Trench and across a corner of the Cabinet Mountains
where it occupies the valley of Rapid Lightning and Trout Creek. It
is probable that the old gravel-filled valley, which lies between the
low line of hills in the trench and the Selkirk Range, and upon which
Sandpoint Creek now flows, is the old pre-glacial valley of Pack River.
If a low patch of moraine were removed from the valley east of Colburn,
Pack River could again be made to flow southward, and if the pre-glacial
drainage were restored, it would flow out through the wide, flat, gravel-
filled valley south of Sandpoint on which Algoma and Round lakes are
now located, and then to the stranded Hoodoo Valley near Lacledo.

Since the retreat of the Wisconsin ice, the Clark Fork has cut a
narrow gorge through the siliceous beds of the Striped Peak formation
at Cabinet, where it has possibly entrenched at one side of its former
channel and has built up the large delta at its mouth. Most of the
streams have been attempting to clear their valleys of the glacial
deposits since the last retreat of the ice.
ORE DEPOSITS

HISTORY OF MINING DEVELOPMENT

The Clark Fork district has the distinction of being one of the youngest producing mining districts in the state. The first production of lead-silver ore was made about 1913, but the district received little attention until some high grade lead-silver veins were discovered in 1928. Their exploitation has made this one of the most important mining districts in northern Idaho outside of the Coeur d'Alene district. Deposits of copper and gold in some parts of the area were known for many years previous to the lead-silver discoveries, but none of them ever actively produced.

The earliest discovery of minerals in the Clark Fork district is not definitely known, but it is probable that some of the copper and gold veins were located and prospected shortly after the discovery of ore in the Pend Oreille district in 1888. By 1905, the Dougherty prospect, a lead vein, near Lake Darling, had been explored by surface cuts and a shallow shaft. The old Campbell prospect near Denton had also attracted some attention, while a number of other showings were known to exist.

During the period between 1905 and 1923, a number of mines and prospects were extensively developed. Several thousand feet of tunnels were driven on the Bonner vein, a gold prospect on Trestle Creek. The Auxer property at the head of Wellington Creek was also revived and active development work started shortly after the world war that has continued until the present. The copper deposits on Howe Mountain were also actively explored, but work on them has been seriously hindered as a result of constant litigation between the two largest properties, the Clarisa and Copper Giant. Another copper prospect, the Carpie, near Cabinet has been explored by shaft and tunnels, but only necessary development work has been done for a number of years.

Shipments of lead-silver ore were first reported in 1913 when the Lawrence Mining and Milling Co., Ltd., which has subsequently been reorganized as the Lawrence Consolidated Mining Co., installed a 50-ton concentrator. Since then the company has marketed small amounts of rich concentrates annually. This property remained the only lead-silver producer until 1928, when the veins of the Elsie K mine were discovered and have subsequently contributed annually to the output of the district.

The discovery which attracted most attention was that made in 1926 on the east end of Howe Mountain, which has subsequently been
incorporated as the Whitedelf Mining and Development Company. The history of the discovery is important, for it adds to the likelihood that other deposits of lead-silver ore may be found, which are now concealed by a heavy overburden and dense growth of timber. The principal vein was uncovered in the course of road construction, but the discovery received little comment until the uprooting of a large tree during a severe storm disclosed some high grade galena in another vein a short distance away. Prospecting was transferred to the newer discovery, but the mineralization proved disappointing in depth compared to the excellent showing at the surface, and work was retransferred to the first vein, which has subsequently yielded practically the entire production of the mine. This high grade vein required little capital outlay and yielded a profit from the very start, and so holds the unique distinction of having paid its way from the "grass roots." The property was equipped with electrical power late in 1927 and work began on a shaft that in 1925 had been sunk 200 feet below the main level. This shaft with drifts at 100-foot intervals greatly enlarged the reserves of the mine, and in the late part of 1928 and early part of 1929 a modern flotation plant was installed to treat the milling ore. Prior to its installation considerable milling ore had been sent to outside plants for treatment, a procedure which yielded a handsome profit.

The development and continuous production at the Whitedelf attracted general attention to the district and has resulted in further discoveries by other operators, and the relocation of many of the old abandoned prospects on Goat Mountain and in other parts of the district. The most important of the more recent discoveries is that of the Whitcomb lease within the very limits of the town of Clark Fork on which important disclosures were reported during the summer and autumn of 1928. Several other promising discoveries have also been reported since the present studies were made, but no opportunity was afforded to revisit the district. One of these is reported on Antelope Peak and another south of the river.

PRODUCTION

The annual and total output of the mines was not wholly ascertained. Since 1913, the Lawrence mine has marketed lead-silver ores valued at more than $80,000; much of this when lead was worth less than six cents per pound and some of it when lead was at four cents. The output of this mine is mainly in lead, as it does not carry as high a content in silver as do the other producing properties.
The Elsie K mine has maintained a steady and increasing production since its discovery in 1923. Until the middle of 1927, it had shipped more than 14 cars of high grade ore carrying from 88 per cent to 63 per cent lead and from 48 to 50 ounces in silver per ton. Later production has not been assembled, but the mine has shipped steadily throughout 1928 one or more cars per month, and, in addition to the hand-sorted ore, has also marketed several cars of milling ore. Production increased steadily in 1929. Under the efficient manner in which the mine is worked, the property will continue to be a valuable producer for many years to come and will probably show a steadily increasing production as reserves are continually blocked out.

The chief production has been from the Whitekelf mine which began shipping in July, 1926, and which in less than a year and a half had marketed 95 cars of hand-picked ore valued between $2,000 and $2,500 per car. These cars carried from 40 per cent to 50 per cent lead and 40 to 50 ounces in silver per ton. Statistics assembled show that the total production for the last five months of 1926 and for the twelve months of 1927 was 184,043 ounces of silver and 2,305,423 pounds of lead. To this may be added 63,645 ounces of silver and 1,160,891 pounds of lead in 1928. Production was greatly reduced during the time the shaft was being sunk and the ore blocked out at lower levels, but with the mill in operation in 1929 the production will probably show a very decided increase.

No other properties have yet been placed on a producing basis, although if the disclosures reported on the Whitcomb lease are sustained, this property will probably be placed on the list in the very near future, and likewise several other properties.

GENERAL CHARACTER OF DEPOSITS

The deposits of the Clark Fork district are mainly replacement veins and in this way resemble the deposits in the Coeur d'Alene district. There are in addition some veins which are distinctly fillings of fissures and these more nearly resemble the kind in the Pend Oreille district, although the list of minerals which they contain differs somewhat in kind and proportion.

Silver and lead are the chief valuable elements of the Clark Fork ores. They are associated in the same veins, the lead in galena, and the silver mainly in tetrahedrite. Zinc is present in most of the lead-silver veins, but usually not in sufficient quantity for shippers to be penalized. Other minerals in the district have so far not been productive of valuable ore. Copper occurs in veins distinctly different mineralogically
from the lead-silver veins, although gradation may be found between them. Gold also occurs in veins that differ from both of the others, although here again every gradation may be found. For reasons of adequate and systematic treatment, the deposits of the district may be grouped conveniently into those of lead-silver, copper, and gold, according to the leading metal which they contain.

A further division of the lead-silver deposits into two distinct classes is feasible and even advisable. This division is dependent on the temperatures at which the minerals were deposited as interpreted from the accessory gangue minerals which they contain. They may be classed as mesothermal deposits,1 formed at moderate temperatures and at moderate depths beneath the surface, and as hypothermal, those formed at higher temperatures and probably even greater depths beneath the surface. The present valuable deposits are those of the mesothermal class and they occur in the rocks south of the Hope fault. The other class lies north of the Hope fault. The classification may, therefore, be made geographic as well as genetic, and the geographic classification is herein used in describing the deposits of lead-silver and their mineralogy.

MINERALOGY OF THE ORES

The district has a long and interesting list of minerals, as many as 36 mineral species being recognized, and the list is probably not complete. Some of the minerals occur in all kinds of deposits, but some are characteristic of only certain types. For convenience, they will be treated under several headings as primary metallic minerals, gangue minerals, and secondary minerals or products of alteration, each listed in order of value of metal or other distinctive features. It has been necessary in this treatment to include some sulphides, really gangue minerals, with primary metallic minerals, and reserve for the gangue minerals those of non-metallic character. After the enumeration and brief description of the minerals, the ores and paragenesis of each group of deposits will be considered individually.

PRIMARY METALLIC MINERALS

Galena.—Lead sulphide (PbS) is the principal ore mineral in the Clark Fork district and occurs in variable amounts in the gold veins and some of the copper veins. It generally has a cubical cleavage, but some of it has gneissic grain and highly veneered slickensided surfaces where the veins have been faulted by post-mineral movement. It is

usually associated with variable amounts of tetrahedrite. In some of the deposits near Clark Fork the galena replaces siderite, but in several brecciated sideritic veins the galena occurs as rounded, botryoidal grains in open pores or as excellent crystals, some of them twinned. It may contain considerable silver, but as a source of silver it is greatly inferior to tetrahedrite.

_Tetrahedrite._—The mineral tetrahedrite (4Cu₃S·SbS₃) commonly known as "gray copper" is a mineral which furnishes most of the silver of the ore. This mineral has a variable composition and contains other elements among which silver is common. It forms a valuable constituent of the lead-silver ores near Clark Fork, where the amount of silver in the veins is directly proportional to the amount of tetrahedrite present. The gray copper can be readily recognized in the hand specimens of the ores from the Whitedolph and Elsie K mines, where it is particularly abundant. It is recognized microscopically in all the other veins nearby. Usually the tetrahedrite occurs in fractures or cleavage cracks in the galena or along the margins, suggesting that the tetrahedrite in the main crystallized later than the galena. It also replaces the earlier formed minerals, siderite, sphalerite, and galena. The sphalerite and galena belong to the same stage of mineralization as the tetrahedrite, but the deposition of the tetrahedrite outlasted that of sphalerite and galena. A single fracture filled with the silver-rich variety, freibergite, which has a reddish brown streak as distinguished from the black streak of the less silver-rich tetrahedrite, was found in the copper vein of the Clarinda property. This mineral cut all others and is clearly the last to be deposited. Tetrahedrite also occurs in notable amounts in another copper prospect, the Carpenter.

_Sphalerite._—Zinc sulphide (ZnS) commonly referred to as zinc blende or blende is rather widely distributed in the ores of the district, except in the copper ores. The lead-silver deposits near Clark Fork south of the Hope Fault contain only small amounts of sphalerite, which occurs as yellow to brown or reddish grains or masses with crystal boundaries against the galena. Sphalerite is somewhat more abundant in the ores in Mountaın Mountain and in some of the gold veins of the Trestle Creek region. The sphalerite in the deposits north of the Hope fault generally has a black color, due to some iron contained in isomorphous form. This, also known as "black jack," usually contains abundant minute inclusions of pyrrhotite and chalcopyrite arranged along cleavage or crystallographic lines, as illustrated in Plate XII. No deposits of sphalerite of economic value have yet been discovered.
Chalcopryite.—Copper iron sulphide (CuFeS₂), commonly known as copper pyrite, is the chief copper mineral in the Clark Fork district, where it occurs in massive form associated with quartz and ankerite. It is a mineral very widely distributed but generally present in only small amounts except in a few localities. It occurs as minute blebs in the sphalerite of some of the deposits, and in some it is intimately intergrown with tetrahedrite. It usually carries gold.

Gold.—Free gold was not recognized megascopically in any of the ores or in any of the oxidizedcroppings, but its presence is indicated by assay. The chalcopyrite carries some gold, and it is also possible that the sphalerite or galena may carry small amounts. Analyses of pyrrhotite showed it to be gold-free, and likewise pyrite taken from several reported gold properties.

Pyrite.—Iron pyrite (FeS₂) is widely distributed throughout the district, and is found in variable amounts in nearly every deposit. The pyrite has normally a nearly white to pale yellow color and occurs in minute cubes, sometimes striated. It is associated with other sulphide minerals as inclusions and rarely occurs in massive form. A few deposits have pyrite as the most abundant mineral. It is not abundant in the lead-silver veins. The pyrite is usually shattered and the fractures filled with other sulphides. In one deposit, pyrite is replaced by both sphalerite and galena. It is very noticeable that the pyrite is the only metallic mineral to form by replacement in the country rock both in the walls and in fragments included in the vein.

Pyrrhotite.—Pyrrhotite (FeS₃ to FeS), known also as magnetic iron pyrites, is an abundant associate of the ore minerals north of the Hope fault and is the chief metallic gangue mineral of the lead-silver deposits on Goat Mountain. The pyrrhotite occurs usually in massive granular form and may be distinguished from pyrite by its faintly coppery color. It has the property of being attracted by a magnet. It has crystallized before the lead and zinc minerals, but usually contains inclusions of pyrite or arsenopyrite. The pyrrhotite is non-auroferous. Pyrrhotite is a diagnostic thermal mineral and its presence in a vein indicates that temperatures were high during the deposition of the ore minerals and that the deposit is probably hypothermal.

Arsenopyrite.—The sulpharsenide of iron (FeAsS), also known as arsenical pyrites or mispickel, is a minor ingredient of some of the lead-silver veins, especially those which contain pyrrhotite. The mineral is recognized in some of the ores on Goat Mountain and occurs abundantly in the Blue Creek mine over the line in Montana. Its
presence may be easily overlooked even when a considerable quantity occurs.

**GANGUE MINERALS**

*Siderite.*—Iron spar or spathic iron (FeCO₃) forms the chief gangue mineral of the lead-silver veins near Clark Fork south of the Hope fault, where it occurs as a replacement of country rock and a filling of fissures. The siderite is normally massive, pale brown, fine to moderately coarse granular, but crystals of curved rhombohedral habit line cavities in several of the veins. The siderite shows replacement by sphalerite, galena, and tetrahedrite, and was deposited distinctly ahead of the others. These minerals usually replace the siderite along rhombohedral cleavage cracks. This becomes most evident on microscopic examination. The siderite is manganiferous and upon weathering becomes dark brown to black, which distinguishes it from the ankerite in the copper veins, which becomes a pearly golden brown.

*Ankerite.*—Most of the gangue mineral in the copper veins probably has the composition of ankerite (2 CaCO₃, MgCO₃, FeCO₃) where it occurs in rhombohedral crystals. Qualitative tests show the presence of abundant iron with the lime, and magnesiu. Ankerite may be considered a dolomite in which the magnesia has been more or less completely replaced by iron. The carbonate is white to faintly buff in color and turns pale brown when slightly weathered. Ankerite differs from siderite in its white to grayish color when fresh, whereas the true siderite is always a clean light buff on fresh fracture. When completely oxidized, siderite gives a dark brown to black manganiferous limonite, while ankerite yields a light brown ocher. The ankerite is peculiar to the copper veins alone.

*Dolomite.*—Calcium-magnesium carbonate (CaCO₃MgCO₃) probably occurs as a vein mineral in the copper veins on Howe Mountain and in the Carpie vein near Cabinet. However, it is always ferriferous and cannot be distinguished from ankerite except by chemical analysis. The ferriferous dolomites had best be classed as ankerite.

*Quartz.*—Silicon dioxide (SiO₂) is widely distributed in the mineral deposits in the Clark Fork district, forming the principal filling of many of the veins. The quartz was introduced in several stages in many of the vein fillings. Its usual occurrence is as white to colorless massive vein quartz, but in many deposits an earlier vein filling of quartz has been brecciated, and the cavities are lined with drusy quartz crystals. In some veins three stages of deposition are recorded: an
early massive filling accompanying the deposition of chalcopyrite; a second deposition in part as crystals accompanying deposition of ankerite in fractures of the earlier filling; and a third deposition in fractures which cut all the other minerals. Jasper, a fine-grained siliceous material heavily impregnated and colored by reddish iron oxide, is also an abundant filling in the Carpie vein and in several others near Cabinet. Quartz is the chief non-metallic gangue mineral of the ores on Goat Mountain, but occurs in small amounts in the lead-silver veins near Clark Fork. In the mesothermal lead-silver deposits, it was brought in during the second stage along with the galena, sphalerite, and tetrahedrite.

Sericite.—Sericite is a variety of muscovite or white mica that is of distinct importance to the student of ore deposits, because it is commonly formed by hydrothermal action on igneous or other rocks and occurs as a replacement of the wall rocks of many metalliferous veins. This type of alteration is by hot alkaline waters and it is such waters which have usually deposited metalliferous ores. The sericitization causes a bleaching of the rock accompanied by blurring and disappearance of the outlines of the original minerals, assumption of a greasy or soapy feel, especially when moist, and the accession of small crystals of pyrite. The mineral is commonly very fine-grained and imparts a distinctly silky luster to the rock. Under the microscope, sericite appears as brightly polarizing scales and flakes aggregated into confused masses. It often resembles talc and most of the "talc seams" of the prospectors is sericitized fault gouge. Many formations in the Belt series contain sericitic members, which, however, have no relation to the ores. The wall rock and inclusions of wall rock of most of the deposits in the Clark Fork district contain variable amounts of sericite usually associated with more or less chlorite.

Chlorite.—The term "chlorite" is the name of a group of minerals rather than a single species. The chlorites are essentially hydrous silicates of iron, alumina, and magnesia, in both composition and structure related to the micas and normally formed by alteration of biotite or hornblende. Most of them are characterized by a green color. Chlorite occurs in very fine scaly deep green forms along with biotite in the vein of the Lucky Strike group on Goat Mountain. It occurs in many other veins in the district, replacing fragments of quartzite or other wall material that are included in the veins, and is a minor part of the vein filling of the Patten prospect, where the original wall fragment has been wholly destroyed. Chlorite is abundantly developed in the walls of most of the veins as a result of hydrothermal alteration.
Calcite.—Calcium carbonate (CaCO₃) occurs as one of the gangue minerals in a number of the veins in the Clark Fork district, particularly those on Goat Mountain and to lesser extent in the copper veins on Howe Mountain, where it is associated with other carbonates. Large rhombohedral crystals occur in some parts of the vein on the Bonner property on Trestle Creek, and this mineral forms the chief filling of the nearby Patten vein.

Biotite.—Black mica, or iron mica, was noted in one of the veins on Goat Mountain, apparently forming a minor part of the original filling. Biotite also occurs in the walls of some of the veins in the Trestle Creek district, due to hydrothermal alteration and replacement of the quartzitic wall rock.

Hornblende.—A silicate of lime, magnesia, and ferrous iron, with variable amounts of alumina and ferric iron, is abundant in most of the igneous rocks in the district. It also occurs in several of the veins. Hornblende occurs in a small vein on Goat Mountain, accompanied by biotite and chlorite, and as small crystals in many of the quartz veins in the dioritic sills. It is also found in fragments of included wall rock in the veins that cut the dioritic sills. The mineral is normally dull black in color.

Epidote.—A silicate of lime, ferric iron, and alumina (H₂O.4CaO.3(Al,Fe₂)₂O₆.8SiO₄) occurs as a gangue mineral in the Dougherty vein near Lake Darling, associated with garnet, quartz, pyrite and galena. The deposit is in a replacement along a fissure in a quartz diorite sill and the epidote has probably formed by replacement of the hornblende. Seams or veinlets of epidote also occur in a sill near the Auxer vein. Epidote is abundant in a recent discovery on Kootenai Point.

Garnet.—Garnets reddish to reddish brown color, probably the variety “almandite” (3FeO.Al₂O₃.8SiO₄), occur as a gangue mineral in the Dougherty vein accompanying galena, pyrite and quartz, and lesser amounts of epidote. The garnets occur in irregular masses several inches across and are distributed throughout the vein. A few are well crystallized and exhibit highly modified crystal faces. The garnets indicate high temperatures during the deposition of the ores, and they probably formed by replacement of the diorite wall, inasmuch as the vein is a replacement along a fissure and not a contact metamorphic deposit.

Feldspar.—An alkali feldspar, probably orthoclase (K₂OAl₂O₆.6SiO₃), occurs in minor amounts in the vein at the Bonner mine, associated with quartz, pyrrhotite, galena, sphalerite, calcite and chalc
pyrite. The presence of the feldspar and pyrrhotite indicate high temperatures at the time the vein minerals were deposited.

*Magnetite.*—Magnetic iron oxide ($Fe_2O_3$) is among the gangue minerals in the Alamo vein, where it is associated with specularite, quartz, and chalcopyrite. The crystals are small and are best recognized in polished surfaces, although large masses are common, more or less intimately associated with the specularite. The presence of magnetite in the vein probably denotes high temperatures during the deposition of the vein minerals. Magnetite is apparently an abundant mineral in a discovery that was reported in May, 1928, on Kootenai Point, near Sandpoint.

*Specularite.*—Specular hematite ($Fe_2O_3$), which has a metallic luster and gray to black color but with reddish streak or powder that serves to distinguish it from galena, with which it is frequently confused, occurs abundantly in the Alamo vein on Howe Mountain, associated with magnetite, quartz, chalcopyrite, and other minerals in minor quantity. The specularite takes lath-shaped forms, some of them an inch long and also in platy or scaly forms. Some of the specularite has formed by replacement of the magnetite. The specularite is another mineral that has diagnostic properties, for its occurrence denotes high temperatures at the time the minerals were deposited.

*Tourmaline.*—Tourmaline is a complex borosilicate of aluminum and various other bases as ferrous iron, lime, magnesia, etc., and may be found in minor amount with quartz in the Patten vein on Trestle Creek. It occurs as bundles of dark greenish needles along fractures in the quartz and greatly resembles hornblende in external appearance. Tourmaline is another mineral that is formed only at high temperatures and its presence indicates a deposit of hypothermal origin.

**SECONDARY MINERALS OR ALTERATION PRODUCTS**

Because of the recent glaciation, which scoured off the upper parts of the veins and in so doing removed the oxidized and enriched zones, the list of secondary minerals or products of alteration is small and such minerals have little or no value.

*Anglesite.*—The lead sulphate ($PbSO_4$) is the first mineral formed by the breaking down of galena under the influence of oxidation. It surrounds lumps of galena or is inserted between the core of parent galena and an outer crust of cerussite. The anglesite is usually compact, massive and has a characteristic ashy-gray color. The anglesite at early stages replaces galena along cleavage cracks. The mineral was
recognized in the surface ores at the Whitnel mine and at the Dougherty prospect, and probably occurs in the outcrops of other lead deposits.

Cerussite.—Lead carbonate (PbCO₃) is found in minor quantities in the oxidized cruppings of some of the lead veins, where it forms as a crust on the anglesite as the result of reaction with carbonate solutions. It also occurs as brilliant white crystals in cavities. It has no value as an ore mineral in this district.

Chrysocolla.—This hydrous copper silicate (Cu₅Si₄O₁₂·2H₂O) occurs in several of the copper veins on Howe Mountain as a secondary copper mineral. It is much less common than malachite in the oxidized ores. It normally has a fine, waxy, blue-green to green color and is seen as massive or botryoidal crusts or scales on free surfaces or forms impregnations in the wall rock. Minor amounts of chrysocolla are also associated with copper pitch ore.

Copper Pitch ore.—A dark brown to light brown or black, impure, copper silicate, containing variable amounts of iron and other substances. It is found in streaks through the chalcocite that replaces chalcopyrite in the ores on Howe Mountain and is usually the first product from the breaking down of the chalcopyrite through oxidation.

Covellite.—Cupric sulphide (CuS) occurs as a secondary mineral replacing galena in the Alamo vein on Howe Mountain. The mineral is characterized by a deep indigo blue, but was recognized only in polished surfaces. It is probably found in other veins which carry both copper and lead minerals.

Chalcocite.—Cuprous sulphide (Cu₂S), commonly known as copper glance, occurs in small quantities in the surface zone of the copper veins on Howe Mountain where it replaces the chalcopyrite. It is best seen in polished surfaces, although it may be recognized microscopically in the Alamo vein. Minor amounts of bornite may accompany the chalcocite in some places.

Malachite.—Green copper carbonate (2Cu₂CO₃·H₂O) is the most common of the secondary oxidation products of chalcopyrite in the district, forming greenish stains or small crusts where the primary copper mineral has been exposed to atmospheric agencies or meteoric water. It also occurs in radiating acicular crystals or fibers in some of the outcrops.

Erythrite.—Hydrous cobalt arsenate (3CoO·As₂O₅·8H₂O), also known as cobalt bloom, occurs as a thin coating on the surface of the Patten vein in the Trestle Creek district as beautiful pink, earthy
incrustations. It is formed as an earthy alteration product from cobaltiferous minerals, possibly smaltite. A few bright, tiny grains of a metallic mineral were noted in the vein, but the grains are too small to be definitely identified.

Marcasite.—Marcasite (FeS₂) is found in the ores of Goat Mountain as a secondary mineral after pyrrhotite. It assumes peculiar concentric and blob-like structures in the pyrrhotite, which it replaces.

Mellite.—Hydrated ferrous sulphate (Fe₂(SO₄)·7H₂O), also known as coppers, was noted in several deposits as a white efflorescence on decomposing sulphides, usually pyrite. It is readily soluble in water.

Psilomelane.—Psilomelane is a hydrous manganese oxide of somewhat doubtful composition that is rather widespread in occurrence in the oxidized lead-silver ores of the district in impure black earthy form or mixed in small proportion with limonite. The psilomelane with limonite is derived from the oxidation of the manganiferous siderite and occurs in the outcrop as a blackish stain or as earthy ochreous forms. Much of the limonite is darker brown in color than is common for this mineral, due to its manganese content.

Pyrolusite.—Manganese oxide (MnO₂) is found in the vicinity of the Walter prospect near Hope and was noted in one or two other places. The mineral takes the form of needle-like crystals as much as an inch long associated with specular hematite and appears to be a primary mineral. Minor amounts were distinguished in association with psilomelane in the oxidized cappings of some of the lead-silver veins, secondary after manganiferous siderite. The principal recognizable difference between pyrolusite and psilomelane is that pyrolusite is commonly crystalline in appearance and is lighter in color, whereas psilomelane is usually black and amorphous.

Limonite.—Hydrated iron oxide (2Fe₂O₃·3H₂O) is very common in the oxidized portions of some of the deposits of the Clark Fork district. It occurs as hard and compact jasper material, as soft ochreous masses, and as cellular or spongy, dark velvety brown masses. Limonite results from the decomposition and oxidation of iron-bearing minerals, especially the iron sulphides and carbonates. In the veins, limonite results from the oxidation of the iron-bearing sulphides as pyrite, pyrrhotite, chalcopyrite and arsenopyrite; from the alteration of iron-bearing carbonates as siderite, ankerite, and ferriferous dolomite; and from the oxidation and hydration of the oxides, magnetite and hematite. Much of the limonite in the Clark Fork locality has been derived from siderite and, as the siderite is somewhat manganiferous, the limonite is also dark and manganiferous.
LEAD-SILVER ORES

The two classes of lead-silver deposits, the mesothermal and hypothermal, which occur on the south and north sides of the Hope fault respectively, have certain minerals characteristic of each type of deposit that do not occur in the other and in addition show unlike stages of mineralization or a different paragenesis. These two classes have essentially only sphalerite, galena, and tetrahedrite in common and show considerable variation in the proportion of these. Some other minerals occur in minor but variable amounts in each, as quartz, calcite, arsenopyrite, and chalcopyrite, but not all of these are recognized in every deposit. The greatest distinction between the two is the presence of siderite as the chief gangue of the deposits on the south side of the Hope fault and quartz and pyrrhotite on the north side.

ORES SOUTH OF THE HOPE FAULT

The lead-silver deposits south of the Hope fault in the small area near the town of Clark Fork are very similar to the deposits in the Coeur d'Alene district in the nature of their minerals and their paragenesis. The lead-silver ores consist predominantly of galena with a variable but considerable amount of tetrahedrite and lesser amounts of sphalerite, pyrite, arsenopyrite, and chalcopyrite, with a non-metallic gangue composed principally of siderite, but with minor quantities of quartz and calcite. The proportion of all of these minerals varies. Arsenopyrite and chalcopyrite were recognized in but one of the veins and pyrite is usually so scarce in all of them that its occurrence is a matter of comment. The quartz is also inconspicuous and in some veins was most easily recognized in polished surfaces. Calcite was found in a few small stringers with siderite, quartz, and tetrahedrite. The siderite is the chief filling of some of the veins, but those that are most valuable have it in only minor quantities, having in its place solid, compact seams of galena and tetrahedrite. The pyrite when noticeable is seen in tiny, striated cubes in the sideritic portions of the veins or in the wall. Sphalerite occurs in most parts of the veins from a mere trace to as high as four and even six per cent, but rarely in sufficient quantity to make recovery advisable nor does it seldom invoke a smelting penalty. Some of the sphalerite has a pale yellow color, but in one of the veins of the Whitedale property it is pale red. Some of the galena is the coarse-grained, cubical kind, but much of it is fine-grained and steel, with slickensided surfaces and shows granulation. It is always intimately associated with variable amounts of tetrahedrite, although locally tetrahedrite may predominate. This intimate
mixture has altered the usual appearance of the ore to a dull gray and has lowered its specific gravity in comparison with a simple galena ore. In some veins the tetrahedrite is recognized only as minute grains within the galena or as minute veinlets replacing the galena along cleavage cracks, as shown in Plate IX, B.

The silver content of the ore is directly proportional to the content in tetrahedrite, although the galena has probably some silver in solid solution. As the galena and tetrahedrite are not sorted, it is customary to relate the ounces of silver to the unit or per cent of lead, a standard that is not scientific, but perhaps unavoidable. The best ore carries about an ounce of silver to the per cent or unit of lead. In the Elsie K and Whitedelf mines, the tetrahedrite is easily recognizable in the ore without microscopic study and locally may form one quarter of the filling. In the Lawrence mine, the tetrahedrite is recognized only as minute grains in the galena and the ore carries 11 to 12 ounces of silver in concentrates with 70 per cent lead.

The list of secondary minerals is not large and includes only unimportant amounts of anglesite and cerussite along with limonite and manganese oxides in the upper several feet of the veins. In several veins the oxidation extends to depths of 20 or 30 feet, but without enrichment. The siderite, because of its manganiferous nature, gives a nearly black limonite as well as some psilomelane and pyrolusite in the weathered zone.

**Paragenesis of the Minerals**

The deposition of the ore has taken place in two clearly separate stages, although it is the result of but one period of mineralization whose prevailing order of deposition as seen in the stopes and confirmed by polished surfaces was siderite, pyrite, arsenopyrite, quartz, pyrite, sphalerite, galena, tetrahedrite, and chalcopyrite. At most mines, sufficient structural disturbance occurred between the stages of deposition to make the mineral assemblages of each stage clearly distinguishable. In the first stage, siderite, pyrite, and arsenopyrite are the leading minerals; in the second stage, quartz, sphalerite, galena, and tetrahedrite, accompanied by subordinate pyrite and chalcopyrite.

In some of the veins that consist mainly of siderite, the two stages are distinctly recognizable. The veins of the Ralph property on Antelope Peak and one of the veins on the Whitedelf property are of this nature, and both show the early filling of siderite with scattered crystals of pyrite thoroughly brecciated by movement along the vein. Many of the open spaces, which were developed, are only partially filled with grains or crystals of galena and sphalerite. Some of the siderite is also
veined and crusted by quartz. Where the sulphides increase in abundance, the siderite is replaced by them and in those veins that are composed essentially of clean-cut bands of sulphides, the siderite takes the form of scattered, rounded, residual grains usually veined by the other minerals. Many specimens were found in which the quartz, the galena, the sphalerite, and the tetrahedrite, either together or individually, replaced the siderite along the rhombohedral cleavage cracks and at more advanced stages thoroughly veined and seamed the siderite. Usually quartz accompanied one or more of the other minerals. The relation between the siderite, pyrite, and arsenopyrite is not so definite, although all three were deposited at the same time, but their sequence is not clear.

The quartz, which accompanied the sulphides, shows replacement of the siderite, but it does not show replacement by its own mineral accompaniment. The sphalerite generally preserves its typical granular form against the galena and tetrahedrite, but in some of the veins it was shattered, probably by movement along the vein during mineral deposition, and the fractures have been cemented as well as enlarged by replacement by either galena or tetrahedrite or both, as shown in Plate IX, A. The tetrahedrite is in general younger than the galena, for it fills cracks in the galena or replaces the galena along cleavage lines and from its borders. In some cases, the tetrahedrite occurs in minute grains in the galena, highly suggestive of contemporaneous deposition of the two. Sphalerite and galena belong to the same stage of mineralization as the tetrahedrite, but the deposition of the tetrahedrite outlasted that of the sphalerite and galena. In the very few places that chalcopyrite was detected, it was intimately intergrown with the tetrahedrite, which indicates that it, too, was about the last mineral to be deposited in the general sequence.

The sequence of mineralization and the two stages of mineralization are essentially the same as in the Coeur d'Alene district, where the lead-silver ore consists dominantly of argentiferous galena in a gangue of siderite or quartz or both, and accompanied by variable amounts of sphalerite, pyrite, tetrahedrite, and several other minerals. The prevailing order of deposition of the principal minerals also remains the same. In the Pend Oreille district, a third stage is present, with chalcopyrite, polybasite, or proustite, as the additional minerals.

ORES NORTH OF THE HOPE FAULT

The mineralization in the lead-silver deposits on the north side of the Hope fault shows a greater complexity than on the south side,
A. PHOTOMICROGRAPH OF POLISHED SURFACE OF ORE SHOWING RELATION OF TETRAHEDRITE TO SPHALERITE

This specimen from the Eldo K mine shows shattered dark gray sphalerite (S) remnant and in part replaced by younger light gray tetrahedrite (T). This illustrates the intimate association of the tetrahedrite with sphalerite and the sequence of their deposition.

B. PHOTOMICROGRAPH OF POLISHED SURFACE OF ORE SHOWING RELATION OF TETRAHEDRITE TO GALENA

This specimen from the Whittoff mine shows the light gray tetrahedrite (T) replacing galena (G) along cleavage line. The specimen brings out the intimate association of the two minerals and offers evidence of their sequence of deposition.
because of several deposits which do not exactly conform to the class. The deposits on Goat Mountain and adjoining parts have essentially the same assemblage of minerals and the same sequence of deposition, but a few isolated deposits like the Dougherty at Lake Darling have a somewhat different list.

The deposits on Goat Mountain consist essentially of quartz and pyrrhotite, with variable amounts of galena, sphalerite, pyrite, arsenopyrite, chalcopyrite, and calcite. These ores in general carry lower values in silver than the siderite-lead deposits and apparently contain very little tetrahedrite, which was rarely recognized in polished surface and never in the hand specimen. The sphalerite has characteristically a deep black color with a reddish brown streak. The sphalerite also forms a greater proportion of the vein filling than it does in the other class of lead-silver deposit and should any of the veins on Goat Mountain be of sufficient size to warrant exploitation, the sphalerite would probably prove a troublesome ingredient and would have to be separated from the galena. The galena occurs in cubical form, but it frequently is found in fine-grained, granular masses intimately associated with pyrrhotite. The arsenopyrite is always a variable ingredient and may not be noticed unless it is in considerable quantity. In the Blue Creek mine, two miles from the state line in Montana and studied as a representative type of the Goat Mountain mineralization, the arsenopyrite is locally abundant and in some specimens forms half of the sulphides. The pyrrhotite, usually the predominant sulphide, occurs either as large massive grains or seams in quartz or intimately mixed with arsenopyrite, sphalerite, and galena. The chalcopyrite is seen as inclusion within the sphalerite, but in the Blue Creek mine it occurs in small patches with the other sulphides. Calcite is locally abundant in some of the veins, but is lacking in many of the others. Biotite and hornblende were found in one vein on Goat Mountain. Pyrite occurs in every vein. In some quartz veins on Goat Mountain, it is the only sulphide.

The Dougherty prospect near Lake Darling shows a different mineralization. Galena is the predominant sulphide and it is accompanied by quartz, pyrite, garnet, epidote, and minor amounts of chalcopyrite, hornblende, and biotite. The vein occurs in a quartz diorite sill and the silicates were probably developed by replacement. The garnet occurs in large granular masses composed of aggregates of reddish crystals scattered throughout the vein quartz. The greenish epidote is infrequent.

A deposit somewhat similar to the Dougherty occurs on Kootenai
Point about four miles east of Sandpoint. This consists mainly of magnetite and pyrite with galena, quartz, epidote, and calcite. The epidote, garnet, and magnetite are indicative of high temperatures or hypothermal conditions.

The secondary products are essentially the same as those south of the Hope fault.Anglesite and cerussite are exceedingly rare. The limonite has its more usual yellowish to orange color, because of the lack of manganese in any of the minerals. The most interesting of the secondary products is marcasite which occurs as a replacement of pyrrhotite in the outcrop of the veins on Goat Mountain.

PARAGENESIS OF THE MINERALS

The paragenesis of the minerals also differs from that in the lead-silver deposits south of the Hope fault. Here the deposition of the ore has taken place in essentially one stage as against the two distinct stages in the other lead-silver deposits. A single uninterrupted stage is perhaps not strictly true, for the quartz which was deposited first invariably shows a slight brecciation that preceded the introduction of the sulphides, but the brecciation has been such as usually to escape notice and two-stage division is not here made. The prevailing order of deposition of the principal minerals as recorded in this stage is quartz, pyrite, arsenopyrite, pyrrhotite, sphalerite, galena, chalcopyrite, and calcite.

The quartz is deposited in some veins as a filling of open fissures and in others by replacement of the country rock, subsequently minutely fractured prior to the sulphide stage. The pyrite invariably takes its own crystal form in the fractures in the quartz and in the walls. The other sulphides show the same relations to the quartz, except that they usually do not assume their crystal forms in the replacement.

The relation of the pyrite and arsenopyrite is not wholly clear as the two minerals are seldom in contact, but they are probably contemporaneous, although it is possible that the pyrite was converted to arsenopyrite under the action of arsenic, which accompanied the mineralizing solutions. The arsenopyrite always maintains its sharp, crystal boundaries against all the sulphides, except possibly pyrite. The pyrite is usually corroded or shows various stages of replacement by pyrrhotite, sphalerite, and galena.

The pyrrhotite, which is generally abundant in all these veins, contains inclusions of both pyrite and arsenopyrite or fills in as a cement
A. PHOTOMICROGRAPH OF POLISHED SURFACE OF BLUE CREEK ORE SHOWING INTRAMIC RELATIONSHIP OF THE MINERALS

Dark gray sphalerite (S) is most abundant and the grains are in part cemented by galena (G) showing a rough surface. Other minerals are pyrite (P'), light gray pyrrhotite (P), and calcite (C). This intimate relationship can be explained only by mutual crystallization and shows the difficult problem involved in separating the minerals in ore dressing.

B. PHOTOMICROGRAPH OF POLISHED SURFACE OF BLUE CREEK ORE SHOWING RELATION OF ARSENOPYRITE TO GALENA AND PYRRHOTITE

The arsenopyrite (A) is cemented by both pyrrhotite (P) and galena (G), which indicates their age relations. In turn the galena surrounds the pyrrhotite, which further indicates that it finished its crystallization last.
A. PHOTOMICROGRAPH OF POLISHED SURFACE OF BLUE CREEK ORE SHOWING RELATION OF SPHALERITE TO ASBENOPYRITE

The arsenopyrite crystals (A) are enclosed in the sphalerite (S) as well as in a band of galena (G) which passes through the specimen. The relations indicate that arsenopyrite crystallized first and was followed in turn by sphalerite and galena.

B. PHOTOMICROGRAPH OF POLISHED SURFACE OF BLUE CREEK ORE SHOWING BANDING

This section brings out the intimate bedding of much of the ore, in this specimen between the sphalerite (S) and pyrite (F). The intimate association again shows the difficulty of metallurgical separation.
around them, but it, too, presents its own characteristic form against the sphalerite and galena which indicates clearly its position in the sequence of deposition. In addition, some pyrrhotite usually occurs as minute rods or blebs arranged in rows probably along crystallographic partings in the sphalerite as though unmixed from a solid solution. A similar arrangement of chalcopyrite in sphalerite was noted in many of the specimens.

The sphalerite maintains its own form against the galena, usually as more or less rounded grains cemented or enclosed by galena. In some polished specimens, it forms a cement or matrix for the pyrrhotite or arsenopyrite (Plate XI). The galena shows cementing relationships to all the sulphides except the chalcopyrite. In the Regal veins the chalcopyrite is about contemporaneous with the galena, but in the Blue Creek vein it cements the galena. Calcite, wherever it occurs in these deposits, fills around all minerals and is clearly the last to be deposited. It usually occupies the center of mineral-bearing seams or veinlets.

In some specimens the intimate relationships are such that they can be explained only by mutual crystallization, although even in the same specimens a definite overlapping sequence can be ascertained (Plate X, A).

The marcasite is of considerable interest as it occurs in some of the veins as a secondary mineral replacing pyrrhotite. In its replacement it assumes peculiar concentric and bleb-like forms, the blebs usually joined together as if by strings.

The mineralization described above is in many ways similar to the mineralization in the Pine Creek region of the Coeur d'Alene district, where pyrrhotite is one of the minerals in the ores. The sequence of the minerals in the two districts is virtually the same.

The paragenesis of the garnet-epidote bearing vein near Lake Darling is not so easy to determine. The quartz-diorite wall has been intensely silicified and the hornblende and biotite converted to epidote. Pyrite is also widely disseminated in the silicified wall. The garnet occurs in the more siliceous parts of the vein and the epidote near or in fragments of the wall. The garnet has perhaps developed in part from the feldspar and hornblende of the diorite with perhaps some addition of material from the vein solutions. The sulphides are later than the silicates. They usually cement them and also give some indication of replacement. The sulphides give a general sequence of pyrite, galena, and chalcopyrite, the last two essentially contemporaneous.
COPPER ORES

No geographic division of the copper ores is necessary, as all the deposits that were examined are south of the Hope fault. This type of deposit is wholly unlike the lead-silver deposits in the near vicinity, as the ore is composed mainly of chalcopyrite with a quartz-ankerite gangue, an association that has not been recognized in any of the lead deposits. In several of the veins, minor amounts of galena have been found, usually the result of a younger stage of mineralization which may offer a genetic connection between the two types of deposits.

Tetrahedrite accompanies the chalcopyrite in several veins and is noteworthy abundant in the Carpie vein. It also occurs in minor amount in the Clarinda vein and the Bumble Bee, but is only rarely seen even in polished section.

The chief interest of the copper ore is in the general nature of the carbonate gangue, which consists in addition to the ankerite of considerable ferriferous dolomite. These minerals have a light gray to white color and usually occur in large to small rhombohedral crystals, in some places forming the greater part of the vein but in others subordinate to the quartz. Good crystal outlines of these minerals may be found lining cavities or clefts in the vein.

The chalcopyrite shows an association with the quartz, and to lesser extent with ankerite. Pyrite accompanies the chalcopyrite and quartz in most of the veins, but it is a minor mineral; likewise galena and tetrahedrite. One vein departs from the general list of minerals given and has chalcopyrite associated with quartz, specularite, magnetite, pyrite, galena, and only a very small amount of the ankerite gangue. The Carpie vein also contains jasper or a ferruginous siliceous cement in addition to the other list of minerals. Most of the copper deposits have a small gold content, the gold in some form being associated with the chalcopyrite.

The secondary minerals are inconsequential, but the incipient oxidation has produced some chalcocite, covellite, malachite, chrysocolla, and limonite.

PARAGENESIS OF THE MINERALS

The deposition of the copper ores has in general taken place in three clearly separate stages in most veins with sufficient structural disturbance between the stages of deposition to make the mineral assemblage of each one clearly distinguishable. These stages are invariably more pronounced than those of the lead-silver deposits. As not all the veins
show the same stages of deposition, it is necessary to consider several of them separately. The increased number of stages shown by the copper veins over that of the lead-silver suggests that the copper minerals were deposited earlier and have suffered longer from structural adjustments along the fissures and that new solutions were re-introduced a greater number of times. In only one vein, the Alamo, are all the minerals clearly the product of one slightly interrupted stage and this particular deposit serves to bind all within a single general period of deposition.

In many of the veins the minerals deposited in the first stage consist of quartz, pyrite, and chalcopyrite. In only the Carpie vein are older stages recognized. In this vein an early filling of quartz has been brecciated by movement along the vein and the fractures cemented by a ferruginous or jasper cement and the whole again brecciated and the fractures sealed by solutions which deposited more quartz along with chalcopyrite and pyrite. The quartz-chalcopyrite stage, which is first in most veins, thus corresponds to the third stage in the Carpie vein. The quartz in the usual first stage was slightly brecciated by movement before the pyrite and chalcopyrite were introduced, for the latter generally occur in fractures and show replacement. The chalcopyrite followed the pyrite, for it invariably shows partial replacement of the pyrite, a process that has involved shattering of the pyrite and enlargement of the fractures by replacement as well as by corrosion of shattered inclusions, as illustrated in Plate XIII, B. Slight movement along the vein was apparently continuous during this stage of mineralization.

The second general stage is very pronounced, for it has involved a thorough fracturing or brecciation of the quartz-chalcopyrite filling that was followed by the introduction of new solutions which deposited more quartz and the ankerite-ferriferous dolomite gangue. This stage is common to all the copper veins except the Alamo. The quartz of this stage occurs in variable amounts, usually deposited first in the fractures and coated by the ankerite, although equally as common, the ankerite has been deposited directly in the fractures without a sign of quartz. It is particularly significant that the carbonate solutions have enlarged the fractures in the early vein-filling by replacing not only the quartz, but the chalcopyrite as well, and in some parts of the veins have wholly replaced those minerals and have encroached upon the walls. This has an important economic bearing in that the copper deposits in places have probably been impoverished by the introduction of the carbonate solutions which dissolved the chalcopyrite and left ankerite in its place.
The third stage is less pronounced than the others, but the earlier fillings have been broken by rather widely spaced fractures and the new solutions deposited quartz, and, in some fillings, additional chalcopyrite, galena, and tetrahedrite. In many fillings the quartz occurs in drusy vugs crusting the ankerite; in others, in seams cutting the earlier fillings. The chalcopyrite deposited in this stage is of no consequence. It is found usually in thin seams or grains along minute fractures and cleavage planes in the carbonate, but is not always present. Galena accompanies the quartz in the Clarinda vein, where it either fills in the spaces between the third stage quartz crystals or builds well-formed crystals in the open cavities as a crust on the carbonate. A thin film of tetrahedrite (freibergite) was found in one of the quartz veinlets in a specimen of the Clarinda ore which belongs to this or possibly an even younger stage. Tetrahedrite was probably introduced at this stage at the Carpie and Bumble Bee veins, where it shows especial selective replacement of the chalcopyrite. Sulphides of the third stage are not sufficiently abundant to have any appreciable value.

That all the minerals are the products of one general period of mineralization is made clear at the Alamo vein, where the sequence of deposition has been quartz, magnetite, specularite, quartz, pyrite, chalcopyrite, galena, and ferriferous carbonate. The quartz, magnetite, and specularite were deposited more or less contemporaneously as shown by mutual crystallization, but part of the specularite has developed by replacement of the magnetite. The reason for the deposition of the magnetite and specularite is probably due to the high temperature of the solutions. This stage is probably equivalent to the jasperoid stage in the Carpie vein. The chalcopyrite contains many inclusions of specularite, magnetite, and quartz. The position of the galena is more difficult to fix, but it is always associated with chalcopyrite in such a way that they appear nearly contemporaneous, although some of the galena has rounded inclusion of chalcopyrite in it. The ferriferous carbonate was apparently deposited last.

Surficial processes of alteration have induced some secondary sulphide minerals, among these chalcocite and covellite. The chalcocite occurs as a replacement of chalcopyrite, beginning along crystal boundaries and acting most vigorously from the specularite contacts. The covellite forms as a replacement of galena, or after chalcopyrite in contact with galena. The galena is more susceptible to the attack of oxidizing solutions than is either pyrite or chalcopyrite that may be in contact with it as indicated by the study of many polished surfaces.
GOLD ORES

The list of minerals in the gold deposits are essentially those of the lead-silver deposits north of the Hope fault. The main reason for this classification seems to be the lack of a suitable place to put those deposits which are too lean in lead or zinc to be of economic value unless gold actually accompanied them. This has apparently been true in a few deposits which contain a little gold in addition to minor quantities of galena, chalcopyrite, and sphalerite, but some of the deposits herein considered carry less gold than the copper deposits on Howe Mountain. This list of minerals, therefore, is mainly pyrrhotite or pyrite with variable amounts of galena, sphalerite, and chalcopyrite in a quartz, or, less commonly, calcite gangue. Pyrite is the most abundant mineral in the Auzer vein, which contains in addition galena, chalcopyrite, and tetrahedrite. This vein probably runs higher in gold than do the others. Arsenopyrite accompanies the pyrite in the McWilliams prospect at the base of Goat Mountain. The deposits along Trestle Creek have mainly pyrrhotite or pyrite with galena and sphalerite. The sphalerite has the usual black color so typical of that of the high temperature lead deposits. Erythrite or cobalt bloom was found at the surface of the Patten vein, suggesting that some primary cobalt mineral is present. This vein also carries tourmaline in a calcite gangue in addition to pyrite, pyrrhotite, and a little galena. An alkali feldspar was observed in the Bonner vein, but it was subordinate to the quartz and pyrrhotite, the principal vein filling.

Assays of pure pyrrhotite from some of the veins showed absence of gold. The same result was obtained with some of the pyrite. In what form or association the gold occurs was not determined. Free gold was not detected in any of the veins, nor in the oxidized croppings. Probably the gold is either disseminated in minute grains in the quartz or is associated with chalcopyrite or galena.

PARAGENESIS OF THE MINERALS

These deposits in common with others north of the Hope fault show essentially a single stage of deposition only slightly interrupted by structural disturbance. The sequence is the same as in the lead-silver deposits north of the Hope fault with a deposition first of quartz followed by pyrite, pyrrhotite, sphalerite, galena, and chalcopyrite. That this sequence is the product of only a single period of mineralization is evident, for in the Bonner vein many minute veinlets containing interlocking crystals of pyrrhotite, chalcopyrite, sphalerite, and galena in quartz are common, as shown in Plate XIII, A, and their relations
prevent any other inference. Much of the black sphalerite is also crowded by minute blebs of pyrrhotite and chalcopyrite arranged in lines or rows along crystallographic partings.

In the old Campbell prospect, the pyrite has been brecciated and veined by both sphalerite and galena. The process has been dominantly replacement. In the same deposit the sphalerite shows replacement by the galena which supplies additional proof of the sequence of deposition as some movement occurred concurrent with mineral deposition.

The presence of the pyrrhotite in most of the veins and the occurrence of tourmaline and feldspar with pyrrhotite in others indicate that the gold deposits were formed at high temperatures or under hypothermal conditions.

DESCRIPTION OF THE DEPOSITS

DISTRIBUTION

The mineral deposits are widely distributed throughout the Clark Fork district, but the greatest concentration occurs in a zone several miles wide, which extends on either side of the Hope fault from Montana to the Purcell Trench. The deposits of present commercial value are, however, grouped in a comparatively small area near the town of Clark Fork. Although the deposits of all types are more or less widely distributed, the different metals distinctly favor certain areas.

A geographic classification and distribution of the lead-silver ores has already been made with those of hypothermal character grouped north of the Hope fault and those of mesothermal character on the south side of the fault. By far the greater number of deposits north of the Hope fault occur on Goat Mountain and extend eastward into Montana, where several deposits have been extensively developed. A few deposits occur near the town of Hope, but these have not shown much promise. Two other deposits lie well within the Cabinet Range; one near Lake Darling and the other on the north fork of Grouse Creek. The present valuable deposits of lead-silver ores are, however, south of the Hope fault in the range of hills north of the Clark Fork, on the east end of Howe Mountain, on Middle Mountain, and on Antelope Peak. Several other prospects are south of the river in the Coeur d'Alene Mountains.

The copper deposits are mainly south of the Hope fault. Several were reported in the main Cabinet Range, but these were not visited. This type of deposit occurs in two well-defined zones, lying east and west of the lead-silver deposits. The largest number of copper veins is on Howe Mountain, west of the lead-silver veins, and in the adjacent
A. Photomicrograph of polished surface of ore showing relation of sulphide minerals to quartz.

The veinlet containing pyrrhotite (P), sphalerite (S), and galena (C) in vein quartz whose relations can be explained only by assuming essentially mutual crystallization of the sulphides. The quartz maintains crystal boundaries against the sulphides.

B. Photomicrograph of polished surface of ore showing relation of chalcopyrite to pyrite.

This specimen from the Copper Giant vein shows shattered pyrite (mineral of high relief) cemented and partially replaced by chalcopyrite (C) and illustrates the movement which occurred along the fissures during deposition of early stage sulphides in the copper vein.
A. Photomicrograph of polished surface of sphalerite showing pyrrhotite in partings

The light gray pyrrhotite (P) is apparently in narrow lines and in blobs along crystallographic planes in the sphalerite as though representing an annosing of a solid solution.

B. Photomicrograph of polished surface of sphalerite showing inclusions of chalcopyrite

The light colored chalcopyrite (C) occurs in tiny blobs or grains arranged along crystallographic lines in the sphalerite (S) as though also representing an annosing of a solid solution.
part of the Coeur d'Alene Mountains south of the Clark Fork. These have been sharply set off from the lead-silver deposits by the Pack-saddle fault. The other zone of copper mineralization is near the Montana line centered about the town of Cabinet.

The gold deposits are all in the main Cabinet Range. Several included in this class lie near the Hope fault, one at the base of Goat Mountain and the other northeast of Denton Siding. Most of them are situated along Trestle Creek, but one on which much money has been expended lies in a glacial cirque at the head of Wellington Creek, a few miles northeast of Hope.

**GEOLOGIC DISTRIBUTION**

The mineral deposits occur almost wholly in the sedimentary Belt series. In this distribution, all members of the Belt are represented, but those deposits of greatest present value are in the Wallace rocks. Only the batholiths and stocks are notably free of mineralization.

The deposits north of the Hope fault are in the Prichard formation and in the sills. However, one occurs in a shear zone in lamprophyre, and one in a joint plane in granodiorite. In Montana, the Burke and possibly the St. Regis have deposits. The hypothermal lead veins on Goat Mountain are enclosed wholly in the quartzites and shales of the upper Prichard.

South of the Hope fault, the deposits are mainly in the Wallace formation, the lead-silver deposits on Howe, Middle and Antelope mountains in the middle and upper part. The copper deposits on Howe Mountain are in the Wallace and underlying St. Regis. The other deposits of copper are in the Striped Peak. So far as the character of the country rock is concerned, any member of the Belt series can contain mineral deposits, for the control of mineralization has been largely structural and any formation which can produce fractures and fissures through which the solutions can migrate might now hold deposits. Formations distinctly siliceous or quartzitic might perhaps produce better fractures and fissures and as in the Coeur d'Alene district be better fitted for the development of ore bodies, but in this district such formations are not in the places of strongest mineralization.

**STRUCTURAL RELATIONS**

**RELATION TO FAULTING**

The most intense mineralization has been in areas of marked structural disturbance, particularly in the major zones of faulting, and, as already stated, the greatest concentration of mineral deposition is along
the Hope fault zone. Deposits in other parts of the area are also in major fault zones, although none of them are as large as the Hope. In the Grouse Creek region, the mineralization is in the zone of one of the large intrusion faults. The vein near Lake Darling is also in a zone that has been faulted and brecciated by the intrusion of a granodiorite stock. In the Trestle Creek region, the veins are not far from the batholith and are near intrusion faults of rather uncertain magnitude. Some deposits are near the Packsaddle fault along Johnson Creek. In fact, very few deposits lie in areas that have been little disturbed by faulting.

None of the large breaks, however, have ore deposits, but the mineralization has been in fractures and fissures that were developed within the rocks during the structural disturbance which caused the major faults. The larger deposits of ore are thus confined to the general zone of most pronounced structural disturbance, but the ore bodies favor minor fractures, few of which have sufficient displacement to cause noteworthy offset of the formations at the surface. The smaller fractures have less gouge to impede circulation than the large faults, and are therefore more suitable as channels for ore-depositing solutions.

Many of the minor fractures, however, are not so much related to the movement along the major faults as to lifting forces which attended igneous intrusion. In the line of hills between the Hope fault and the Clark Fork, the mineralization is mainly along minor faults of steep reverse nature that could have been formed by the lifting force of an underlying magma. These steep-angled reverse faults have a minimum of gouge and in general show much more mineralization than normal faults in their own vicinity, which have heavy zones of gouge. The relationships here suggest that part of the faulting has been due to the lifting or thrust effects of an underlying stock which came up an already weakened zone and added further to its disruption, as explained elsewhere. The combination of broad zones of extensive faulting with nearby igneous intrusion has apparently caused localization of the ore deposits in the Clark Fork district.

STRUCTURE OF LEAD-SILVER VEINS SOUTH OF THE HOPE FAULT

The lead-silver veins south of the Hope fault are characteristically replacement deposits along fissures and fractures. These may be divided into two classes, depending on the relation of the veins to the bedding of the sedimentary rock. Locally they are termed fissure and bedded veins, indicating that the first cuts the bedding of the sediments
at a wide angle and that the second occurs between the bedding planes or approximately so. None of the veins are truly bedded, for each one cuts the bedding at a very slight angle that is generally observable only when a considerable length of the vein is examined, either along the strike or along the dip. This type is really a fissure vein where the movement, either a distinct slippage or a brecciation, is approximately parallel to the bedding. Most of the veins on Middle and Antelope mountains are of this kind, all of them having relatively flat dips (less than 20°) when compared with the distinct fissure class. The displacement has not been great, but little movement is required in the weak beds of the Wallace formation to cause widespread brecciation of the rock and its conversion to gouge. These zones of brecciated country rock in this particular area have in part been more amenable to the circulation of mineralizing solutions than has the distinct fissures which show greater displacement and more gouge.

The largest ore body so far developed is in a distinct fissure with a steep dip which cuts the strike of the bedding at a wide angle. Many fissures of this nature occur in the district but only a few have been more than lightly mineralized, probably due to excessive gouge. Most of the fissures have a prevailing trend to the northeast with a dip greater than 45° to either the northwest or southeast and are apparently members of a more or less definite system of fracturing or fissuring. Another set trends to the northwest and these are more prominent and show evidence of greater displacement. They also have more gouge and are usually only lightly mineralized and are less prone to develop ore bodies than the other. These fissures cut across the northeast group and show later movement. Several of the mineralized fissures bear reverse relationships suggestive of an underlying magma, but the character of all could not be ascertained.

The deposits, whether fissure or bedded, are tabular in form and the ore shoots occur within them without any clearly recognizable order of distribution except that, in the fissure class, intersecting fractures or fissures have provided for wider ore shoots in some places because of increased opening and brecciation of the country rock. A common characteristic of all these veins is their tendency to swell and pinch, both along the strike and dip. This character may be in part controlled by the nature of the wall rock or the thickness of the gouge developed from the wall, for the pinching of the vein or ore body is apparently accompanied by an increase in the quantity of gouge, and the swelling with its disappearance, true of both fissure and bedded veins. The swelling of some parts of the veins, however, may be due
to local bulging of the walls because of movement along a warped surface which leaves openings that may be filled with mineral. Many of the veins are relatively persistent and have been developed for many hundreds of feet along the strike. None of them have been explored more than three hundred feet below the surface and these show the same characters as higher. The veins are all narrow, the ore shoots seldom more than a few inches in thickness, but composed of compact seams of ore.

Most of the veins have been cut by a minor system of faults which seldom offsets the veins more than a few feet. Some of these faults have a northerly strike, but some trend nearly at right angles. The latter are the more prominent and displace the veins the greater distance. These faults are probably subsidiary to the later movement along the Hope fault, as some of them show displacement in a horizontal direction and others in a vertical direction. Those with vertical movement are normal in character with downthrow on the south, but those with horizontal movement are mainly in the northerly direction. The veins also show considerable post-mineral movement in the planes of the fissures. This has caused the ore to be fractured and bounded by slickensided surfaces.

**DISTRIBUTION OF ORE IN DEPOSITS**

In most of the veins on the south side of the Hope fault, the ore occurs in solid or compact seams or lenses along either wall of the fissure. In some of the veins, the sulphides are also more or less disseminated throughout the fissured zone, mainly in a feeble network cementing fragments or filling fractures in the rock, widening them by replacement, and constituting milling ore. The concentration of ore minerals into single masses has been of greatest importance and explains the present value of these deposits, for it permits economical removal of vein matter of small thickness without milling, which could not otherwise be profitably handled if the same quantity of minerals were scattered throughout a wider zone. A layer of gouge of variable width lies on either side of the compact seams, which permits the ore to be readily detached from the walls and hand-sorted from the waste. The chief gangue mineral is usually the country rock, unavoidably mixed with the sulphides in mining. Some of the seams contain minor inclusions of partially replaced wall rock and such seams are usually fastened firmly to one of the walls. The seams swell and pinch, and this character is usually explained by the irregular replacement of the wall. The seams of clean-cut ore range from a fraction of an inch to as much as 30 inches wide and locally as much as 7 feet 10 inches, but most of
them are narrow. The Pearl vein of the Whitedelf property has an average width of 9.2 inches along the main tunnel. The bedded vein of the Elsie K mine has an average width of four inches. Seams of galena as low as two inches wide have been profitably removed from some of the veins because of the compactness of the ore and the low mining costs. Again, disseminated ore in a body 11 feet wide has been opened in a fissure vein on the Elsie K property.

The ore shoots normally end in or against heavy zones of gouge. The compact seams tend to break into stringers in some of the gouge zones, and, although the total quantity of ore remains the same, the increased amount of wall rock that must be handled makes the ore of milling grade. Some of the fissured zones have a narrow compact seam of lead-silver minerals along either wall with disseminated ore through the remainder. In some veins, the sulphides form a coating or occur as granules between the pores of a brecciated siderite filling, but the deposits are too low grade to be worked at present.

ALTERATION OF THE WALL ROCK

Many stringers of sulphides transgress the walls of the fissures, some of the seamlets being composed of siderite and some of sulphides. Each also may be found as impregnations within the wall, usually but a few inches from the vein. The replacement of the country rock is clearly distinguished. The replacement by sulphides has also been accompanied by hydrothermal alteration. The sedimentary rock assumes a bleached appearance near the veins or fissures, and has a distinct greasy feeling. Sericite is developed in the bleached zone as well as minor amounts of carbonates and silica. Pyrite may also be found. About some veins, the country rock has a greenish hue because of the development of chlorite. The alteration is not particularly noticeable at the surface because of the weathering of the rock and because of the usual mantle of overburden. In some places the presence of mineralized rock may be suspected from the occurrence of black manganese stains from the weathering of the siderite that may have replaced the rock along bedding planes or minor fractures.

STRUCTURE OF LEAD-SILVER VEINS NORTH OF HOPE FAULT

The lead-silver veins north of the Hope fault are like those on the south side in that they are mainly replacement deposits, but in addition there are a number which are more properly classed as fissure filings. Both fissure and bedded types are about equally represented, but the bedded differs from those across the Hope fault in that the veins
exactly conform to the bedding of the sedimentary rock. Apparently replacement has been along weak partings in the beds or along slippage planes or joint planes parallel to the bedding. The strike and dip of the bedded veins are controlled by the structure of the sedimentary rocks north of the Hope fault. On the north and west sides of Goat Mountain the structure is simple with few faults to interrupt the continuity of the strata which have a general trend of N. 20° E. and a dip of 15° to 20° to the southeast. On the south slope of the mountain, however, the structure is much more complex and the beds have been generally distributed by faulting, some of the faults with displacement involving hundreds of feet. The beds trend to the northwest and have a moderate dip to the northeast. The bedded veins, of course, behave likewise.

The fissure and fracture system is much the same as directly south of the Hope fault, although less pronounced, and the breaks may be grouped into those trending northwest and those northeast. The northwest set is the more pronounced and, unlike its kind across the Hope fault, is more highly mineralized. The rocks which comprise Goat Mountain are in general more siliceous than the neighboring Wallace rocks and develop much less gouge. This makes them more suitable as mineralizing channels, but unfortunately other factors have been at work which, probably because of the high temperatures, prevented a notable amount of mineral deposition.

The bedded seams have little or no gouge and the sulphides are in general frozen tightly to the walls. Unfortunately these veins are composed largely of quartz with minor amounts of sulphides, mainly pyrrhotite, and for this reason larger veins must be exploited to yield the equivalent of the veins on Middle Mountain and Antelope Peak. The bedded veins on Goat Mountain are in general one to eight inches thick and are not persistent along the strike. These pinch and swell and because of the extreme hardness of the wall rock, usually massive quartzite, the expense of drilling and mining is high.

The fissure veins on Goat Mountain are also composed largely of quartz, either barren or with scattered crystals of pyrite. Several carry small amounts of pyrrhotite and galena. Some of these veins are rather definite fissure fillings, somewhat modified by replacement of the wall. Gouge is usually lacking in all of them. The veins are seldom more than 14 inches wide, and their width is variable. None of them are persistent.

Some unusual structures may be noted in the veins on Goat Mountain. Perhaps the most interesting are the veins in the Regal group,
where a steeply dipping quartz vein mineralized lightly with pyrite occupies the same fissure with a lamprophyre dike and from this fissure vein spring several bedded veins like limbs from the trunk of a tree. These bedded seams from two to eight inches wide are composed mainly of pyrrhotite, galena, and sphalerite with quartz increasing in quantity near the trunk. Apparently temperatures were too high in the trunk vein to permit deposition of the sulphides.

A few bedded seams on Goat Mountain are composed mainly of galena, but such seams are small, probably too small for exploitation. In the Homestake deposit, the sulphides, mainly galena, are sparsely scattered in tiny veinlets in the quartzites along bedding and joint-planes.

The structural conditions are somewhat different at the Blue Creek mine a short distance east of the state line where the ore has been deposited in a fissure zone by replacement. This vein trends to the northwest and dips steeply southwest. The replacement has been by quartz and sulphides, but the quartz forms but a minor part of the deposit. Considerable gouge occurs in the fissure and, as in so many other deposits, the quantity of ore is apparently determined by the quantity of gouge, for with increasing thickness of gouge the mineralization becomes correspondingly lighter. The vein pinches and swells and the replacement has progressed on either wall of the fissure. The ore minerals are irregularly scattered through the vein in tiny seams, lenses, or bands from a fraction of an inch to several inches wide along minor shear planes in the wall rock. In one place, the vein widens to about 12 feet with the sulphides rather uniformly distributed throughout and with altered country rock as the chief gangue mineral. Some of the ore shows a rude banding. Several bedded veins occur in the near vicinity.

The galena-bearing vein of the Dougherty prospect near Lake Darling also shows replacement along a fissure in diorite. The fissure also cuts quartzites, but the mineralization is confined mainly to the diorite, which seems more amenable to replacement. The walls of the vein are fairly regular, but many fragments of wall are included in the vein. The minerals occur in irregular bunches or pockets and in part in bands. The fissure may be traced for several hundreds of feet, but the ore shoot is not persistent. In one place it is nearly four feet wide.

**ALTERATION OF THE WALL ROCK**

The wall rock in general shows only minor degrees of alteration by the mineralizing solutions. In many of the seams on Goat Mountain,
the alteration is shown only by a greenish casing due to the development of chlorite. Sericite invariably occurs in the walls of all of the veins, although it is not always easily recognized. Evidence of hydrothermal alteration is particularly abundant about the Blue Creek vein where the wall rock has a characteristic greenish hue. Biotite and also epidote were recognized in the walls of some of the veins. The alteration is more or less characteristic of that produced by hypothermal solutions.

**STRUCTURE OF COPPER DEPOSITS**

The copper deposits occur in tabular veins usually two to three feet wide along steeply dipping fissures that have been in part enlarged by replacement. Most of the veins follow steeply dipping reverse faults, but in some the nature of the movement is not clearly understood. These veins also pinch and swell in both strike and dip and are generally lenticular. They are remarkably persistent in strike and most of them can be traced for hundreds of feet on the surface and some of them for several thousands of feet. Like the lead-silver veins, this thickness is controlled more or less by the quantity of gouge in the fissure. Some of the veins break up into stringers or send small stringers into either wall. The veins may be grouped into two systems, those which occupy northeast trending fissures and those which trend to the northwest. Movement along the northwest set continued longer than on the other and has caused the latter to be displaced. Mineralization occurs in both fissures, but is most prominent in the northeast set, as this had less gouge to impede the circulation of the ore solutions.

Most of the veins hold many inclusions of wall fragments, usually showing all stages of replacement. The ore shoots within the veins are small and uncertain and apparently have no definite distribution within the veins. In some of the veins, the chalcopyrite is sparsely scattered through the quartz, but in some of the more pronounced occurrences it forms more or less massive bands several inches wide. The largest shoot examined is about 60 feet long on the strike of the vein. The shoot is two to three feet wide and for about 30 feet has eight to twelve inches of nearly solid chalcopyrite, most of it frozen to the hanging wall. The shoot is about as long on the dip.

As the veins of this class have been reopened several times, they show differences in textures, depending on whether later solutions were reintroduced. Where later solutions were not introduced, the vein is a porous mass of brecciated vein quartz, but where subsequent stages of mineralization occurred, the vein breccia has in general been cemented or replaced by ankerite, the ankerite often replacing the wall and there-
by enlarging the original fissure. In some of the veins, open clefts or vugs only partially filled with carbonates remain. The stages of mineralization and the replacement of the earlier stage minerals, including the chalcopyrite, by later stage minerals have been discussed elsewhere. Post-mineral faulting has affected the veins but little, and the displacement so far observed has been slight.

ALTERATION OF THE WALL ROCK

The veins usually show a thin casing of altered wall rock of a light greenish color composed of chlorite, sericite, quartz, and carbonate minerals. Inclusions within the vein also show a similar alteration. The inclusions of wall within the quartzose portions of the vein show less alteration than those that have been caught by the ankerite solutions which in part replaced them. The fragments usually show sharp boundaries against the quartz, but indefinite boundaries against the ankerite. Apparently the carbonate stage was more effective than the earlier stage in producing hydrothermal alteration as well as promoting replacement.

STRUCTURE OF THE GOLD DEPOSITS

The gold deposits occur as fissure fillings and as fissure fillings enlarged by replacement of the wall or detached fragments of the wall. Apparently the only exceptions are the old Campbell prospect near Denton Siding, where the mineralization is in a shear zone in igneous rock, and the Auxer property where the vein in diorite is dominantly a replacement along a fissure. With most of the veins the distinction between vein and wall is very sharp. Most of the veins trend in a northerly direction, but a few follow northwest lines. Only two veins conform to the bedding of the sediments, both on the same property.

The veins generally pinch and swell along both strike and dip. Some of them are less than a foot wide, but some are several feet and are remarkably persistent along the strike, having been traced for several hundreds of feet, and a few more than a thousand feet. Some of the veins bulge into the wall by replacement. The veins show no banding or crustification and the sulphides are scattered more or less uniformly throughout the veins. Many of the veins branch or give off stringers. The veins are usually tight, that is, the vein filling adheres to both walls, but some contain altered seams of gouge. A few of the veins have been cut by post-mineral faults, but the displacement in no case has been great.
ALTERATION OF THE WALL ROCK

The wall rock and the inclusions of the wall show various degrees of hydrothermal alteration. Where the wall is igneous, it has been converted into an aggregate of sericite and chlorite, less commonly with biotite. In addition, the wall usually shows silicification. The quartzitic walls especially in the Trestle Creek district show considerable development of sericite and biotite. Epidote has also been noted in the walls of some of the veins. The alteration about these veins is much like that about the lead-silver veins on Goat Mountain, and is typical of that formed by solutions at high temperatures.

GENESIS OF THE DEPOSITS

RELATION BETWEEN THE SEVERAL GROUPS OF DEPOSITS

The grouping of the mineral deposits into those of lead, copper, and gold was done only for convenience in describing the properties and for the benefit of the laymen who are more interested in the substance of the ore bodies than in their genesis. In the area all transitions may be found: from the pyrrhotite-gold ores on Trestle Creek to the pyrrhotite-lead ores on Goat Mountain, from the pyrrhotite-lead ores to the siderite-lead ores, and from the siderite-lead ores to the copper ores. The gold ores have essentially the same minerals, but in somewhat different proportions, as the hypothermal lead veins north of the Hope fault. One of the pyrrhotite veins north of the Hope fault at the base of Goat Mountain has considerable quantities of siderite, a link which binds this kind of deposit with the siderite-galena veins on the south side of the fault. Some of the copper veins on Howe Mountain have minor amounts of galena or tetrahedrite, which may ally these veins with the siderite-lead veins.

The deposits are also related in form as they are for the most part replacements along fissures and fractures. In those veins that show particularly high temperature characteristics, the process of simple fissure filling predominates over replacement, although fissure filling has invariably been accompanied by some replacement. The differences that exist between the various deposits can be best explained by differences and changes in temperatures during deposition, and to changes of composition of the solutions as deposition continued.

RELATION OF MINERALIZATION TO FAULTING

In order to properly understand the problem of origin or genesis of the deposits, it is necessary to repeat some of the essential facts brought out under structure and show their relation to the mineral occurrence.
The mineralization has in general been confined to areas of most pronounced structural disturbances in relatively subordinate fissures and fractures in the zones of major faulting, such as along the great Hope fault zone. The faulting in the region is largely a consequence of igneous intrusion and was mainly active during the period of intrusion, although some movement continued for a longer time. The linking of the faulting or formation of fissures with intrusion has a very important bearing as the deposits themselves are believed to owe their origin to the magmas, and the ore solutions thought to be introduced before movement along the fissures had entirely ceased, coming late in the magmatic period as well as in the later stages of faulting. Evidence of this is offered by the several stages of deposition in the veins south of the Hope fault, which shows that although the mineralization probably occurred during one general period, the process of ore deposition was interrupted several times by structural readjustments so that the same lodes were reopened at different times and solutions of different composition successively introduced. The recurrent opening of the fractures at different times would satisfactorily explain the observed differences in many of the deposits, for the paragenesis of the ore minerals shows a definite sequence of crystallization and hence a definite change in the composition of the solutions as crystallization progressed. The occurrence of galena in a late stage in one of the copper-ankerite veins is particularly significant of the recurrent opening and the introduction of solutions of changed composition. These late movements along the fissures in most places suggest readjustments within an underlying magma and to which induced stresses in the overlying rocks were repeatedly relieved by slippage during mineralization and even later.

ORIGIN OF THE ORE

The relation of mineralization to igneous activity is seen in the Pend Oreille district1 where the relation between ore deposition and the geologic events following igneous intrusion can be worked out with a degree of assurance seldom possible. In this district, the ore deposition occurred at the close of the post-intrusion linear faults, but still within the range of igneous activity. The mineralization barely preceded the intrusion of lamprophyre dikes which are regarded as a common sequel to the intrusion of granitic rocks. As the ore deposits in that district are cut by these dikes, they were then clearly formed during the period between the solidification of the upper part of the granodiorite magma and the period of intrusion of lamprophyre dikes.

Both the dikes and ore deposits are grouped in the same restricted areas, a factor which suggests that they were derived from a common deep-seated source. The association of the ore and dikes in that region was so nearly contemporaneous that though the ore preceded the dikes, hydrothermal alteration associated with the ore-forming solutions followed dike intrusion.

The grouping of the ore deposits and lamprophyre dikes along the Hope fault zone shows a relationship between them. However, the dikes which have so far been found in mine workings were intruded slightly ahead of the mineralizing solutions and the sequence of events differs in this respect from that in the adjoining Pend Oreille district.

The gradation of the several types of deposits, the paragenesis of the minerals, and the age of mineralization with respect to the general period of magmatic activity all suggest that the ores have been deposited from hot ascending solutions given off from cooling igneous bodies. Umpleby\(^1\) postulates a similar origin for the Coeur d'Alene ores, that the ores are of magmatic derivation and that their source lies in the granitic intrusive which is exposed locally in the region and which in depth is doubtless continuous with the Idaho batholith. In the Clark Fork district, the igneous rocks are more widely distributed and the mineralization is confined about the margins of the granodiorite stocks or above such stocks, as is suggested south of the Hope fault near the town of Clark Fork. The form of the ore bodies—mainly replacements along fissures—indicates that the solutions which deposited the ores at depth were under great pressures, and the mineralogical character of the ores indicates that the temperatures were moderate to high.

**GENETIC DISTRIBUTION**

The distribution of the ore deposits on the two sides of the Hope fault is genetic. Those north of the fault have certain minerals as pyrrhotite, biotite, hornblende, feldspar, etc., which are deposited only at high temperatures. These deposits are grouped relatively near bodies of granodiorite, those on Trestle Creek near the margin of the batholith on the west flank of the Cabinet Range, and those on Goat Mountain near the granodiorite stock on Lightning Creek. Other scattered deposits are also not far from bodies of granodiorite, which are either exposed on the surface or indicated immediately below the surface by contact metamorphism of the sedimentary rock. The upper parts of these veins which formerly may have had mesothermal tenden-

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cies like those south of the Hope fault, have been planed off by erosion and only the roots remain.

The deposits south of the Hope fault indicate that their source is considerably removed from the underlying granitic rock which permitted the solutions to cool somewhat before the present minerals were deposited. The minerals which are found in these veins, except for a single deposit, are those which more characteristically develop at lower temperatures. These deposits are not directly related to the stock on Lightning Creek, for some of the mesothermal veins are nearer that body than some of the hypothermal veins on Goat Mountain. This character is due to subsequent movement along the Hope fault which has brought the two classes of deposits into juxtaposition. But the nature of some of the fissures and their recurrent opening during mineralization suggests an underlying body of granodiorite, and additional evidence is afforded by the occurrence of lamprophyre dikes and even porphyry dikes in this vicinity. The body must exist at considerable depth because the surface rocks show no evidence of contact metamorphism or endomorphism. The greater distance from the source of the solutions has permitted this type of mineralization to take place, and other factors have prevented it from being removed by erosion. The earlier solutions given off probably had higher temperatures than the later (the copper deposits are perhaps an example of the early deposition), but all were essentially lower than those to the north, although, with increasing depth, characteristics of higher temperature will probably be found to prevail and the deposits become more nearly like those on Goat Mountain.

The distribution of the copper on Howe Mountain west of the Pack-saddle fault might suggest post-mineral movement which has brought the lower temperature lead-silver deposits against those of higher temperatures, but this movement lacks field verification. The distribution is best explained by supposing that the locus of mineralization changed as a result of structural disturbance and the later solutions followed the sets of fractures and fissures on the east side of the main fault and deposited the lead and silver minerals therein except for a small amount in the Clarinda vein.

The part that the Hope fault plays in the major grouping of the two genetic types of deposits is a most important one. The mineralization of the area is all within the same general period and the grouping of the two temperature types on opposite sides of the fault plane suggests that movement continued along the Hope fault after cessation of mineralization, and lowered the formations on the south with respect
to those on the north and have thus brought the higher parts of the veins into position alongside their lower parts. Most of this lowering was probably completed before peneplanation, and the middle or upper portions of the veins represented south of the fault have been preserved because they had been dropped below the zone of erosion which effectively planed off the higher parts to the north. Movement continued along the Hope fault even after peneplanation, for in the subsequent uplift the old erosion surface on the north was raised 1,500 feet above the same surface of the south as shown by the discordance in summit levels between the Cabinet and Coeur d'Alene mountains. This later movement has also aided in protecting the mesothermal deposits from removal by erosion and mainly for this reason the Clark Fork district is recognized as a producing district today.

SUGGESTIONS FOR PROSPECTING AND DEVELOPMENT

The most promising part of the Clark Fork district is that which contains the present commercial deposits of lead-silver ore, for here is found the combination of factors believed to be most favorable to ore deposition, namely: extensive zones of faulting and concealed igneous intrusion without notable metamorphism. In this area, the geological conditions are essentially the same as in the Coeur d'Alene district, with the mineralization grouped near the zone of a great west-northwest fracture comparable in every way with the famous Osborn fault. The type of mineralization greatly resembles that of the Coeur d'Alene district, the list of minerals of the two districts and their paragenesis being essentially the same. They are also similar in the character of the deposits, as both are mainly replacement veins. The relatively small area near the town of Clark Fork has apparently been a special locus for mineralization. Because of the heavy growth of timber and the generally deep overburden of glacial till, the area has not been adequately prospected. It is possible that other veins similar to those already developed may yet be discovered, especially on the east end of Howe Mountain, and on Middle Mountain and Antelope Peak. The region immediately south of the river is also worthy of exploration, particularly near some of the larger fault zones such as the Pack-saddle fault. The larger faults and fissures which have developed heavy zones or bands of soft gouge are generally unsuited for mineralization and the search for ore deposits should be confined to the smaller fractures and fissures, especially those of a reverse nature which have developed little gouge, or to those fissures which closely follow the bedding.
The outcrop of the lead-silver deposits is unpronounced because of the usual small size of the veins and the general lack of a resistant quartz gangue. The veins or mineralization may best be detected by the black manganese stains developed by the oxidation of the siderite. The pale greenish, hydrothermally altered wall rock is not a safe criterion, for it may be confused with much of the country rock, especially the Wallace formation, which has a similar color.

The character of the country rock is not one of the controlling factors in ore deposition, although a wall adapted for replacement might be desired, especially a siliceous wall that would fracture freely with a minimum development of gouge. The present economic deposits are in a formation which might be considered unfavorable for mineral occurrence, as the Wallace formation is generally soft and shaly and especially adapted for developing heavy bands of gouge; but it so happens that this formation is in the area with the most favorable structural factors and in the special locus of mineralization. Any promising prospect is worthy of exploitation regardless of the formation that encloses it, but considering the district as a whole, no deposits of consequence need be expected in the granodiorite stocks and batholiths, but only about their margins.

The lead-silver veins are generally narrow, but fortunately the lead and silver minerals occur in massive compact seams, a factor which provides for economical mining and the removal of ore that would be otherwise valueless if scattered through a wide zone of country rock or in a wide vein of worthless gangue. Many of the fissure veins as well as some of the bedded veins contain considerable disseminated or milling ore, but few of the deposits of this type have been sufficiently developed ahead of mining to show reserves that would warrant the installation of a mill or concentrator. Until sufficient reserves have been blocked out to provide for several years run, a mill should not be planned.

Most of the present valuable lead-silver veins are persistently mineralized for great lengths along their strike, but the seams are not uniform in thickness. Some of the apparent pinching is due to the splitting of the compact masses in the heavier zones of gouge where the values are dissipated in small ramifying veinlets which prohibit hand-sorting but which contain potential milling ore. The pinching and swelling of the veins are characteristic along the dip as well as along the strike. If the fissure plane were warped unequally during the movement along its surface, open or more porous zones might be developed and these would offer the necessary room for the expanded
portions of the vein. This has been an important factor, but its occurrence is difficult to forecast. Where movement along the fissure has been in the nature of a shear without the development of too much gouge, the deposit may consist of a wide zone of milling ore. All fissures and shear zones should be examined in this area whether they cut the bedding or are parallel to it, but especial attention should be given to those with but minor displacement. Intersection of fissures has also played an important role in the formation of some ore shoots because of the more open channel and greater permeability of the shattered rock and may therefore be one of the dominant factors in the localization of ore shoots. Reopening of the fissures at the proper time to introduce solution of a given composition has also played a fundamental part in this localization. The deposits south of the Hope fault are developed at moderate temperatures, and should extend to considerable depth above the present working levels. Some of them may soon pinch out, perhaps due to structural factors, but mesothermal characteristics should prevail for many hundreds of feet in depth, and a change should be heralded by the introduction of pyrrhotite into the ores. The depth to which these deposits may be worked probably depends more on the mining costs of hoisting the ore from such small veins than on the actual continuance of the ore bodies.

The deposits north of the Hope fault are of different character, and their economic worth has not been demonstrated. Such deposits as the Blue Creek vein over the state line in Montana encourages the hope that some of the hypothermal veins may have commercial value. In any of the deposits north of the fault, except the Dougherty vein far back in the Cabinet Range, the pyrrhotite forms a goodly part of the vein filling and the galena is generally subordinate. Thus the presence of abundant sulphides suggests that a large part of it may consist of valueless pyrrhotite. The vast area of Prichard rocks in the Cabinet Range in Idaho is worth prospecting for deposits of high temperature origin. Whether the general dearth of prospects over much of this area, except its southern margin, is due to its inaccessibility or to a lack of mineralization is not wholly determined, probably the latter.

The copper deposits are still within the prospective stage, although they have been known and explored for many years. The veins are strong and persistent, some of them may be traced for several thousand feet, but the ore shoots within them are small and uncertain. Most of the copper veins are disappointing and offer little encouragement for intensive prospecting. The copper deposits are like those in the Court d'Alene district where only a very few have been productive.
The gold deposits need to be systematically sampled and assayed before their merits can be determined. Many of the so-called gold deposits are like the pyrrhotite-lead veins on Goat Mountain and probably contain only inconsequential amounts of gold. Other veins are said to contain as high as an ounce to the ton, but it is feared that these assays are on especially selected samples which offer little indication of the actual worth of the veins.

Mines and Prospects

A grouping of the mines and prospects into the several divisions used in the discussion of their mineralogy and vein structure will be followed in the detailed description of the individual deposits. The lead-silver deposits south of the Hope Fault are those of greatest promise and the only deposits that are productive as the report is being written. They will receive greater detail in description than some of the others because of this. The order of treatment will be based largely on the value of their production during 1928, and, if they are still within the prospective stage, on the amount of development work done. The same order will be followed in descriptions of the other classes of deposits, but, as these have not left the prospective stage, the order will depend mainly on the amount of development.

Lead-Silver Deposits South of the Hope Fault

Whiteelf Mine

The Whiteelf mine lies about a mile and a quarter northwest of the railroad station at the town of Clark Fork, on the east tip of Howe Mountain. The hill upon which the mine is situated is not steep or rugged except on the south side, and the only impediment to mining and prospecting is the dense vegetation and thick mantle of glacial drift. The portal of the main haulage level is at the east base of the hill along the Lightning Creek or Spring Creek road.

A number of mineralized fissures occur on this end of Howe Mountain, but only one, the Pearl, has so far been of consequence. These deposits are mainly replacements along steeply dipping fissures within the Middle Wallace, which here shows some calcareous shales and quartzites of greenish and grayish color interbedded with more numerous beds of greemish and bluish shales or argillites. The fissures cut the bedding at a wide angle both in strike and dip as the veins trend nearly east and west and the sediments at nearly right angles to them. Fissure filling in addition to replacement has undoubtedly played an important
role, but its presence is generally masked by the replacement that has invariably enlarged the original fissure.

The most valuable mineral of this deposit is galena, but it is always associated with relatively abundant quantities of tetrahedrite, which is easily recognized in most of the hand specimens. In general, the tetrahedrite, which carries most of the silver, forms from about one-tenth to one-fourth of the ore. The galena and tetrahedrite are accompanied by small amounts of sphalerite, pyrite, siderite, and quartz. Each of the veins shows differences in the abundance of these minerals, but the present productive vein has them in the order given above. The two stages of mineralization are distinctive in these veins, the shattered siderite in parts of the Badgely vein having been incompletely cemented by the younger sulphides. The general order of deposition of quartz, sphalerite, galena, and tetrahedrite is maintained in the second or last stage. In some parts of the veins, the galena has a coarse grained cubical or granular texture, but in other parts the galena has been mashed or finely granulated by later movement on the vein, and, where the tetrahedrite content is especially high, has the appearance of exceedingly fine-grained "steel" galena.

The several fissures, which have been more or less successfully mineralized, are probably a part of a complex branching and intersecting system that has a general trend to the northeast, but differences in their strike cause several of them to join or intersect. Not all the fissures were as well adapted for the circulation of ore-bearing solutions as others, because some of them developed great quantities of gouge which impeded circulation and so prevented the ores from being deposited. The vein most highly mineralized, the Pearl, strikes N. 40° E. and dips 65° to the southeast. The Badgely, also known as the Middle vein, lies about 150 feet to the south of the Pearl at the surface and strikes N. 55° E. and dips nearly vertically. The Badgely is the vein uncovered by the uprooting of the tree during the storm. Both of these veins on the west join a greater fissure, one that has much larger quantities of gouge, known as the Pugh vein, whose strike is N. 70° E. and about 85° to the south. What is probably the eastward continuation of the Pugh is called the South vein or Anderson vein. Several other fractures have been explored near the main highway on the south side of the hill. The fissures are not all everywhere well defined, being characterized in places by wide zones of gouge, in others by wide branching shears which may die out along the strike with the movement taken up by more or less parallel overlapping seams. The ore occurs mainly in those fissures which have rather clean-cut fractures,
and, as even sharp fractures may pass into heavy zones of gouge along the strike or dip, the ore shoots may end by division into stringers in the gouge or by pinching. Intersection of minor fractures with the main fissure, usually at slight angles, has generally determined the occurrence of the wider portions of the ore in the Pearl vein. Post-mineral faults have off-set the veins a few feet in a number of places, but none of the displacements have been serious. Post-mineral movement also in the plane of the vein has broken the ore and has caused polished ore surfaces or slickensides.

The Pearl vein occupies a distinct fissure with reasonably sharp walls. The movement along the fissure has been in a zone three or four feet wide, but the ore generally occurs as a clean seam of solid sulphides along the footwall side of the fracture. In some places, the vein has disseminated ore, usually in the hanging wall, but most of the vein is compact sulphides with a casing of gouge of variable thickness, which forms a sharp division between ore and waste and permits the ore to be readily detached from the country rock. In some of the more gougy zones, the vein divides into stringers and becomes mill feed. The ore has been followed in the vein from the portal of the Norquist tunnel to the Pugh fissure, 500 feet away. In this distance the "high-grade" seam ranges from three inches to 29 inches wide with an average width of 9.2 inches. In one place above the main tunnel, the ore body of solid sulphides widened to seven feet 10 inches, but this bulge was local and the shoot soon exhausted. At the bottom of the 200-foot shaft, the vein maintains about the same characteristics as on the Norquist level, ranging from two to 14 inches. The same tendency to swell and pinch is also shown along the dip. About 90 feet below the Norquist tunnel, the vein nearly pinched out, but with greater depth again enlarged. The ore at the bottom of the shaft is peculiarly fine-grained and is composed of very fine-grained galena and tetrahedrite. The widening of the vein is apparently everywhere determined by the intersection of lateral fissures, which are also mineralized. The swelling and pinching of the veins on the dip is probably in part explained by the difference in the dip of the main and lateral fissures, which would control the degree and direction of brecciation. Post-mineral faults, which have off-set the vein in a number of places, usually have displacements of two to four feet to the south in a horizontal direction.

The hand-sorted ore has from 40 per cent to 50 per cent lead and from 40 to 50 ounces in silver per ton. Although some variation occurs in silver-lead ratios, the average is about one ounce of silver to
the unit of lead. The ore contains only minor amounts of sphalerite and in no place is sufficient to invoke a smelting penalty. A little gold is also reported.

The Badgely vein is an irregular fracture, also offset to the south in many places by post-mineral faults of small displacement. The most extensive mineralization was at the place where the fallen tree first disclosed the vein, but the shoot pinched within a very short distance both on the dip and on the strike. The vein has been explored for several hundred feet by cuts and tunnels at the surface, but on either side of the one shoot it decreases from three feet to several inches, much of the filling being brecciated pyrite and siderite and a few scattered granules of reddish sphalerite and crystals of galena. This vein shows less compactness than does the Pearl. The upper 20 to 30 feet of the vein shows considerable oxidation and has much manganese and limonite material enclosing residual grains of galena. The Badgely vein fails to reach the Pugh vein, for it abuts against a normal fault, which strikes N. 45° E. and dips 29° to the northwest. This fault has seams of barren quartz along it.

The Pugh vein is in general an irregular branching shear, which is in places distributed over a zone more than 30 feet wide. It is a pre-mineral fault with an enormous amount of gouge and may be the dominant member of the whole complex system of fissuring. It shows minor degrees of mineralization, mainly with pyrite, but with small shoots of disseminated galena in two widely separated places. The first of these shoots is 50 feet west of the end of the Pearl vein and the second 170 feet beyond. The shoots are 20 and 25 feet long respectively and two and seven feet wide, but the mineral is not sufficiently abundant to constitute ore. The vein known as the South or Anderson vein is probably an easterly extension of the Pugh. The gouge zone is as much as five feet wide and is very lightly mineralized. It has some tiny seamlets and tiny masses of pyrite, galena, and tetrahedrite.

The several small veins, which occur near the top of the ridge and on the south slope, are small and are only lightly mineralized with galena, sphalerite, siderite, and tetrahedrite. One of the veins has apparently more tetrahedrite than any other mineral, but not enough to be commercial.

The Pearl vein has the greatest promise and seems likely to continue with depth with much the same character as in the higher levels. The width of the ore will probably be determined by the intersection of cross fractures or fissures and perhaps a careful mapping of these will aid in finding new ore shoots. Those fissures, which show consid-
erable movement, as indicated by the heavy zones of gouge, will probably have but inconsequential amounts of sulphides, but as even such fissures may show clean fractures along some parts, they might contain shoots of commercial ore.

**ELSIE K MINE**

The Elsie K mine ranks next to the Whitepolf as a producer of lead-silver ores during 1927 and 1928. The veins are near the road along the east side of Lightning Creek and escaped notice until 1923, although one vein is crossed by the road and another parallels it for about 600 feet only 20 to 60 feet away. Up to the middle of the summer of 1927, mining had been confined to the vein which lies along the upper side of the road and had been opened for more than 600 feet by drifts from several tunnels with portals at the road level. These workings are all shallow as the vein is “bedded” and dips into the hill at a low angle. A short winze was sunk on the vein and drifting both ways opened up much ore. In the latter part of 1927 a tunnel was begun near the floor of Lightning Creek valley several hundred feet below the outcrop, this tunnel on the vein, a steeply dipping fissure, crossed by the road. Considerable milling ore was encountered in the long tunnel and the reserves, which had previously kept pace only with mining, have been enlarged. Most of the production has been of high-grade, hand-sorted ore, but in 1928 several cars of lower grade ore were sent to outside mills for concentration with very gratifying results. For the past several years the mine has been operated by the Hope Mining Company.

The Elsie K mine is fortunately situated on the road and is less than a mile and three-quarters from the railroad station in the town of Clark Fork. The outcrop and earlier workings are several hundred feet above the west base of Middle Mountain and an easy downhill grade assures rapid and cheap transportation to the station.

The veins, bedded and fissure, that have been explored are characteristically replacement veins. These occur in the upper part of the Wallace formation, not far below some of the red beds that are so characteristic of the Striped Peak. The country rock is particularly thin-bedded, a factor which makes for the development of much gouge with only slight movement, especially as the rocks are grayish to nearly black soft shales. The rocks in the vicinity of the veins and on other parts of Middle Mountain have been extensively faulted, usually by faults of minor displacement, but most of the fissures so far prospected have been very lightly mineralized and the more profitable veins have been those that closely follow the bedding.
The vein minerals consist of clean sulphide minerals without a notable admixture of gangue. Galena is the predominant mineral, but tetrahedrite and sphalerite may readily be recognized as well as minor amounts of quartz and siderite. The tetrahedrite may locally comprise as much as a third of the filling. It is usually distinguished from the galena by its fineness of grain, for the galena has a coarse cubical cleavage. The sphalerite occurs in brownish seams and bands a fraction of an inch thick parallel to the walls of the sulphide seams. These sphalerite bands are usually veined by the tetrahedrite and galena and the polished surfaces of specimens reveal that the sphalerite has been fractured or brecciated, and the fractures filled and also enlarged by replacement by either galena or tetrahedrite as shown on Plate IX, B. Little of the early stage siderite remains, but an occasional remnant may be found within the sulphides or more generally in small veinlets in the country rock, unaffected by the later movement which introduced the sulphide minerals. Veinlets of sulphides also invade the wall and enlarge fractures by replacement.

The “bedded” vein only approximately follows the bedding, although the discrepancy can be determined only by very close observation. The vein and bedding trend slightly west of north and dip about 12° to the east. The vein has been explored for more than 600 feet, the early work having been done near its center and south end and the later work near the north end where it terminates against the fissure vein. Its total length is unknown, but it may end on the south against a second fault or fissure whose presence is suggested by a topographic depression. Movement along the bedded fissure has caused brecciation and slippage through a zone several feet wide, but the ore is confined to a narrow high-grade seam from a fraction of an inch to five or six inches wide. Some gouge is developed along the vein, which permits the ore to be readily detached from the walls. The average width of the high-grade seam is about four inches, but a width of even two inches constitutes profitable ore under the economical mining methods due to the softness of the wall and the ease with which it stands without timbering. The ore shoots range from a dozen to a hundred feet in length, having more or less lenticular shapes. In some places, the vein has quartz rootlets or veinlets which join from below. Some of these may represent channels through which the ore solutions reached the fissure. The vein increases in thickness near its north end to six or seven inches, and this is apparently the result of the greater brecciation near the zone of intersection of the bedded and the fissure seams, the additional shattering and porosity providing for a larger ore shoot. It
is probable that the fissure served as the channel for the upward moving solutions and that the solutions spread laterally along the "flatter" brecciated zone where there was less gouge to impede their circulation. Apparently some of the solutions escaped through a broken bedded zone on the opposite side of the fissure as well, but this seam, 40 feet higher, has not been developed. Post-mineral movement has caused more gouge along the veins and has fractured the ore, causing slickensides both parallel to the walls and across them. A number of small normal faults may be seen in the drifts. These have steep dips to either the east or west and in some places off-set the vein two or three feet.

The fissure vein strikes N. 50° W. and dips 40° S.W. The gouge zone suggests considerable displacement, but this assumption is not necessary, as the rocks are soft and easily reduced to the consistency of clay. The gouge zone is from 14 to 18 feet wide and the drag relationships indicate that the movement has been normal with downthrow on the south. In the upper workings, the gouge contains some stringers or seamlets of sulphides in ramifying network, which excludes the possibility that the ore is drag ore and the fault post-mineral, although there has been some post-mineral movement. The vein had been explored in 1928 for more than 600 feet by means of a long tunnel. A raise on the vein encountered galena, probably of milling grade, distributed through a zone about a dozen feet wide. Further exploration has encountered more ore and also a lamprophyric dike that failed to show at the surface.

The occurrence of ore in a clean compact seam in the bedded vein has made milling unnecessary as a rich product can be obtained by hand-sorting. Mining costs are relatively low, as the rocks are easy to drill and the walls stand well without timbering, except along the fissure vein. The blocking of ore has kept pace only with mining, and the reserves are, therefore, difficult to estimate. The work in the long tunnel has shown the existence of ore with greater depth and indicates that the life of the property will be extended for many years. The reserves of milling ore will probably be sufficiently increased in time to justify the construction of a small concentrator.

**Lawrence Mine**

The first shipments of lead-silver ore were made from the Lawrence mine in 1913 when the Lawrence Mining and Milling Company installed a 50-ton concentrator comprising crushers, rolls, two jigs, and three tables operated by a small Pelton wheel from water flumed from Mosquito Creek in whose valley the property lies. Several veins have been
explored on the property, and the total development consists of more than 5,000 feet of tunnels, including a main haulage tunnel 1,249 feet long. Much of the ore has been stoped from above this level. Sinking on the vein has extended 55 feet lower and much of this ore has also been removed.

The mine lies on the steep west slope of Antelope Peak. The mill and portal of the main tunnel are at the foot of the mountain and not more than a hundred yards from the road to the town of Clark Fork, which is less than a mile and a half away.

The veins are of the bedded type in which the fissures are approximately conformable with the bedding. The country rock is the upper part of the Wallace formation, and one of the veins lies in the massive limestone bed that occurs at the top of the series. The sedimentary beds, as well as the veins, trend slightly east of north to north and dip about 30° to the east. The vein that has been most extensively developed is within thin to thick-bedded, grayish to greenish, argillaceous and calcareous quartzites and shales. Several post-mineral faults have disturbed the veins, some of the offsets amounting to more than a dozen feet. Seven roughly parallel veins are reported as outcropping on the property, but only two have been prospected underground.

The mineralization is much like that at the Elsie K: the vein minerals consisting mainly of galena with minor quantities of sphalerite, tetrahedrite, pyrite, siderite, and quartz. The amount of tetrahedrite is considerably less than usual, as it is detected only in polished surface and this scarcity is reflected in the lower silver content of the ores. The sphalerite is also somewhat more abundant than usual, although only one stope has contained sufficient zinc to incur a smelting penalty. Pyrite is generally confined to lightly mineralized shoots, which contain little or none of the second stage minerals, but it is also somewhat abundant in the upper or second vein. Neither siderite nor quartz are abundant and the chief gangue is the country rock mixed with the ore in mining.

The main vein is along a brecciated zone from one to three feet wide with minor seams of gouge throughout. The vein has been mined for about 400 feet along the strike, but the mineralization has not been uniform and the shoots widen and pinch as they do on similar veins. In the richer portions of the shoots, the sulphides occur in bands from an inch to several inches wide at either wall of the fault breccia with disseminated ore throughout the entire vein. In some places, streaks of high-grade ore occur along both walls and the broken country rock between has sufficient disseminated sulphides to constitute milling ore.
In general, the vein lacks the compactness of the Elsie K vein and the Pearl, and hand-sorting is not wholly practical and is not used. In some of the leaner portions of the vein, as well as in some of the richer shoots, the galena occurs in small veinlets or seams in the brecciated rock, filling fractures and replacing the fragments, and also as ramifying veinlets. The lenses of high-grade ore usually end by branching. Some of the stopes had two to four inches of high-grade ore, and where these pinch out the vein was left as pillars. In several places, nearly vertical veinlets of sulphides from one-quarter to one-half inch wide join the vein from below and suggest that in part they may have been the feeding channels for the ore solutions. This relation may also suggest that other veins lie below.

The walls stand well for a vein of such flatness and little timbering is necessary except near faults that have cut across the ore body. In such places, the ground is broken, mashed, and reduced to gouge through zones more than a dozen feet wide.

The long crosscut intersects the vein at an acute angle about 300 feet from the portal and passes through without change in direction for more than 800 feet. Short crosscuts have been run from this tunnel to the vein and the vein stopeled for 400 feet on the strike and about 200 feet on the dip. A fault with much gouge and four-foot displacement cuts the ore body about 100 feet from the south end of the shoot. This fault strikes N. 85° E. and dips 75° S.E., with downward on the south. A second fault lies 100 feet beyond and this has cut the ore body completely off. It is approximately parallel to the first, but the displacement has been greater and has caused shattering or movement through a zone more than a dozen feet wide. The fault is also normal, but the downthrow is on the north. The tunnel was extended beyond the fault, but the vein was not encountered, apparently because the displacement raised the vein above the tunnel level. These two faults are also encountered in the long main tunnel as well as a third fault about 680 feet from the portal. The last strikes N. 85° E., and dips about 80° S.E. It is unmineralized and is probably similar to the other two. Drifting along the fault encountered a dike (?) mineralized with pyrite. As the drift was caved when the property was studied, the dike (?) could not be examined. It is reported to strike N. 27° W., and dip 80° S.W. Material, which has been in the dump for several years, was so decomposed by weathering that recognition of its original character is practically impossible. Pyrite cubes are abundant in the grayish, soft material and it is probable that the dike (?) is an acid porphyry that has been hydrothermally altered.
The winze, which has been sunk on the vein, follows the dip at an angle of about 28°. Drifting has continued both ways on the vein from the bottom of the incline and much of the ore has been removed from here to the surface except for pillars of lower grade ore. Further prospecting at greater depth is advisable.

The second vein, which has been developed and from which a car of ore was at one time shipped, lies several hundred feet higher than the one described above and farther east. The vein has been explored for 225 feet underground, but its full length has not been determined. The vein carries galena and pyrite scattered through one to three feet of shattered country rock in every way similar to that of the other vein, although not as persistently mineralized. The fissure strikes N. 45° W., and dips about 12° N.E. It cuts the bedding at a considerable angle as the sedimentary formation trends due north and dips 20° E. A small pyrite shoot occurs nearby in another vein. Other veins on the property have narrow iron cappings with disseminated galena, but little is known of them.

**WHITCOMB LEASE**

Several veins, which outcrop on the south slope of Middle Mountain within the very limits of the town of Clark Fork, are generally known as the veins of the Whitcomb lease. The veins were discovered either late in 1926 or early in 1927 and by the latter part of the summer of 1927 had been explored by 365 feet of tunnels. Work was discontinued late in August, 1927, but early in 1928 development was again started under new management and continued throughout the year, and, according to newspaper notices, with very gratifying and promising results.

Mineralization is indicated in several places on the property, both in bedded seams and along the steeply dipping fissures. These are in the thin-bedded, grayish to black shales of the upper Wallace formation a short distance beneath the reddish beds at about the same horizon as the Elsie K veins. The sedimentary rocks with their enclosed bedded seams have a general strike of N. 30° E. and dip about 15° S.E., but the beds as a whole have been considerably disturbed and their sequence interrupted by faulting, the larger faults being outlined by gullies.

The chief sulphide mineral is galena and it is accompanied by minor amounts of tetrahedrite, sphalerite, quartz, and siderite. The tetrahedrite occurs mainly as tiny grains and granules about the periphery of the galena masses or fills cracks in the galena. The chief gangue is the country rock involved in mining.
The principal development in 1927 was on a bedded vein. This was explored for about 225 feet along its strike and probably less than 100 feet on its dip. In general character, the vein resembles the Elsie K or the Lawrence, for it occupies a brecciated zone more or less parallel to the bedding. The sulphides occur as more or less compact seams ranging from knife-edge thickness to four inches, swelling and pinching as is usually the case for the veins of this type. A prominent seam of gouge lies along either hanging or foot wall and where it is the thickest the mineralization is the lightest. In general, the compact bands break into several smaller seamlets, each about one-half inch thick, in the heavier gouge zones. These may rejoin again within a short distance. Two small stopes were made on the vein, each about 15 feet. Post-mineral movement in the plane of the vein has fractured the galena and produced slickensided surfaces.

The bedded seam slopes downward from a pronounced steeply dipping fissure, which marks the site of a small gully a short distance west of the main tunnel. This fissure has from several inches to several feet of crushed rock and gouge and shows variable amounts of mineralization. In the early part of 1928, the work was directed along this fissure and several feet of milling ore were disclosed. Later reports indicate that the vein has considerable promise.

**BLAIR AND COLLINS LEASE**

The veins on what is known as the Blair and Collins lease were explored in the spring and summer of 1927, but work was discontinued in the autumn. This prospect is on the northwest side of Middle Mountain, about two and one-half miles north of the town of Gold Fork, and lies a short distance above the road which ends at the base of Goat Mountain.

The prospect is about a quarter of a mile south of the Hope fault in the particularly limy beds of the Middle Wallace formation. It also lies a few hundred yards to the north of another large fault, which has dropped the upper beds of the Wallace in which the Elsie K veins occur against the Middle Wallace, involving a stratigraphic throw of several thousand feet. This fault has been crossed by the road and an excellent section may be obtained in the road-cut. The movement has disturbed the rocks through a zone about 150 yards wide and has developed great quantities of gouge. Its strike nearly parallels that of the main Hope fault of which this is probably a related break. The large fault segment in which the veins occur strikes N. 20° W. and dips about 30° N.E.
Several bedded veins occur on the property, but only one had been explored at the time of the writer's visit. This one nearly follows the slope of the mountain and if it continues with depth will pass beneath the valley floor of Cascade Creek. The vein is like the others on Middle Mountain in that it is along a brecciated zone several feet wide that closely conforms with the bedding. The mineralization is also probably similar, but as only the oxidized zone had been explored the minerals recognized include only the resistant galena mixed with considerable quantities of iron and manganese oxides. The presence of much manganese oxide suggests that the chief gangue is manganiferous siderite. The mineralization is not clearly confined to distinct bands as is usual with most veins of this kind, but is scattered through a zone which widens from six inches to three feet, with the galena and manganese and iron oxides distributed irregularly in small pockets or lenses, or as small stringers cementing the brecciated fragments of altered rock. About 25 tons of hand-sorted galena crusted with the oxides of iron and manganese were piled at the portal of a short tunnel.

RALPH PROPERTY

The Ralph property was discovered many years ago and has been prospected sporadically at different times. This property lies on the north side of Antelope Peak, a short distance east of the Lawrence, and about one and one-half miles from the town of Clark Fork. The total development comprises about 360 feet of tunnels.

This property has an interesting array of joining and intersecting veins, the predominant one along a fissure with a northwesterly trend and the others joining from the northeast or southwest. The veins are all the fissure type and are within the uppermost part of the Wallace formation, which consists of grayish, thin-bedded and flaggy shales whose general strike is N. 10° E. and dip 10° S.E.

The two stages of mineralization are especially pronounced in this deposit, as the main filling consists of brecciated, porous siderite with scattered crystals of pyrite only partly cemented and replaced by seams of quartz and scattered grains and granules of galena and sphalerite. Tetrahedrite probably occurs with the sulphides as well but in subordinate amounts. Inclusions of wall rock also form an appreciable part of the vein filling, these showing all stages of replacement by the early siderite and younger quartz and sulphides.

The main fissure vein is curved and its strike varies from N. 20° W. to N. 50° W. and its dip from 63° S.W. to 44° S.W. It has been followed for 15 feet to the northwest and 85 feet to the southwest from where it
was tapped by a 105-foot crosscut. In the longer drift to the southeast the vein ranges from one to four feet wide beneath six to twelve inches of gouge, but the vein filling is mainly fragments of the wall cemented and partially replaced by siderite and pyrite. In the shorter drift to the northwest, scattered grains and masses of sulphides have been introduced into the shattered siderite and breccia filling on both sides of an eight-inch gouge seam.

Many small stringers containing siderite and sulphides join the main fissure from the southwest side in the shorter drift. This zone is more than 10 feet wide, but its exact magnitude is unknown, as the drift has not extended across the mineralization. The stringers trend N. 10° E. and lie a few feet to the west of a ten-inch vein, which has a parallel trend and which contains mainly siderite with some crystals of pyrite, younger galena, and sphalerite. This vein stops against the main fissure. Three veins also join the trunk fissure from the north, these having the same general alignment as the vein on the south side and dip from 60° to 70° to the west. They have thicknesses ranging from two to twelve inches and their filling is mainly wall fragments in a quartz matrix. The northeasterly set of veins show neither the movement, pre-mineral or post-mineral, of the northwesterly trending fissure nor the extensive recurrent movement of mineral deposition. The mineralization shown along the northwest drift in the main fissure warrants more thorough exploration than was given it at the time of the writer’s visit.

**MOSS PROSPECT**

The Moss prospect was located less than a year before the writer’s visit in 1927. This prospect is south of the Clark Fork delta near the mouth of Johnson Creek and in the area of St. Regis rocks that lie between the creek and the Pucksaddle fault. The property faces the river and lies near the base on the steep slope that forms the north margin of the Coeur d’Alene Mountains.

The mineralization is along a fault whose strike is N. 45° E. and dip 30° S.E. The beds on the east side of the vein strike N. 10° E. and dip 30° S.E., but those on the west strike N. 25° E. and dip 60° N.W. A second fault a short distance to the west restores the bedding to its normal regional trend and dip. The wall rock along the fissure and the included wall fragments show variable degrees of hydrothermal alteration and are converted to a pale greenish aggregate of quartz, chlorite, sercite, and have minor seams of siderite and scattered grains of pyrite. The fissure itself is sparingly mineralized with arsenopyrite, pyrite, sphalerite, galena, and chalcopyrite accompanied by siderite,
calcite, and quartz. The usual sequence of deposition is recorded with
the chalcopyrite forming nearly contemporaneously with the galena,
but carried into later stages. The fissuring extends through a zone
about two feet wide and has developed large quantities of gouge. A
layer of soft black gouge lies along the hanging wall. The upper side
of the gouge is unmineralized, but the undercasing contains scattered
grains and in some places narrow bands of the sulphide minerals.
A few seams or veinlets composed largely of sphalerite occur in some
parts of the brecciated zone. At the time the property was visited the
vein had been explored by tunnel for 55 feet.

WEIR PROSPECT

The Weir prospect is on a small knoll that rises about 20 feet above
the gravel covered flat between Antelope Peak and Sugar Loaf Moun-
tain about three miles northeast of the town of Clark Fork. Some
indications of mineralization occur along a brecciated zone that trends
northeast across an acid porphyry dike into the sandstones and shales
of the Striped Peak formation. The dike, which has the composition
of a quartz monzonite porphyry, about parallels the trend of the Hope
fault. In the brecciated zone it shows some silification and other evi-
dences of hydrothermal alteration. The deposit had been prospected
only by a small cut on the surface.

LEAD-SILVER DEPOSITS NORTH OF THE HOPE FAULT
BLUE CREEK MINE

The Blue Creek mine lies about two miles east of the state line in
Montana, but was visited with the idea that the character of the deposit
and its mineralization might offer additional information on the nature
and genesis of the ore deposits north of the Hope fault and also of the
entire region. The property has been prospected for a number of years
and a car of ore was shipped while the writer was in the field. Many
men were employed at the time and the number was increased during
the following year. The property is about a mile and a half north of
the Hope fault along the east fork of Blue Creek, and is most con-
veniently reached from Heron, Montana, over a road that describes
a great loop to get around a low mountain that lies between the river
and the main Cabinet Range.

A number of veins occur on the property, but only one has been
extensively developed. This is a fissure vein, enclosed by the Burke
formation whose trend is northwest and dip steeply east. The pre-
vailing northeast trend of the sedimentary formations in Idaho has been interrupted nearby because of faulting. Evidence of several faults of considerable magnitude was noted, but their essential features were not determined. Bedded veins are also numerous, generally like those on Goat Mountain, and consist of quartz with variable amounts of pyrrhotite or arsenopyrite, sphalerite, and galena. The main fissure vein is a replacement along a fault which trends N. 32° W. and dips 58° S.W. The quartzitic walls are hydrothermally altered and converted in part to a greenish chloritic schist with scattered crystals of pyrite and in some places with a little siderite.

The Blue Creek ore is essentially a fine-grained aggregate of pyrrhotite, arsenopyrite, sphalerite, and galena, as illustrated on Plate X and Plate XI, rudely banded and with variable but much lesser amounts of pyrite, chalcopyrite, calcite, and quartz. In most of the ore, the sulphides of lead and zinc about approximate in quantity the arsenopyrite and pyrrhotite, but locally any of these sulphides may predominate. Chalcopyrite occurs in only a few scattered places in the ore shoot and is of no consequence. Much of the ore has a more or less faintly banded structure, which is of interest. The bands are composed of small seams of variable thickness, usually less than half an inch, of some particular sulphide alternating with similar seams of other sulphides. The bands are closely spaced and although each zone is particularly rich in some certain sulphide whether pyrrhotite, arsenopyrite, sphalerite, or galena, it is usually intimately associated with minor quantities of each of the others. In some of the specimens, the zones rich in arsenopyrite or pyrrhotite may be distinguished from zones rich in galena or sphalerite, but in many the minerals are so fine grained that microscopic test is necessary. Except for a few coarser bands, the texture is generally so fine-grained that the minerals are difficult to separate from one another even by very fine grinding. (See Plates X and XI.) In a few specimens the early crystals are partially shattered, which suggests that the banding, which can never be traced far in any direction, may be due to movement as the sulphides were being deposited. In some parts of the vein the sulphides occur in reticulating veinlets in fractures in quartz or in fractures traversing the country rock, but this occurrence is subordinate to that first described. Only one period of mineralization is represented, as the minerals usually show intimate relationships that can be accredited only to mutual crystallization (Plate X, A). The general sequence has been quartz followed by pyrite, arsenopyrite, pyrrhotite, sphalerite, galena, chalcopyrite, and calcite.
Much gouge was developed during the pre-mineral faulting and this has played an important part in controlling mineralization. The replacement has been irregular and has occurred along either wall, depending on which side offered least resistance to the passage of the mineralizing solutions. The widest shoot is where the movement has been taken up along several planes, which has more thoroughly brecciated the rock without producing undue amounts of gouge. The ore minerals are more or less irregularly scattered through the vein in tiny seams or veinlets, or in bands of lenticular masses several inches wide with unreplaced fragments of the wall as the chief gangue. The vein was encountered by a crosscut tunnel in its widest part where the sulphides are rather uniformly distributed throughout a sheared wall zone about 12 feet wide. At this place some of the ore occurs in massive seams several inches wide showing a rudely banded structure. At the time the property was visited a drift had been extended to the south for nearly 300 feet, but the ore shoot had become greatly impoverished in about 200 feet and the face of the drift was in a heavy gouge zone showing only slight mineralization. The vein narrows a short distance above the widest shoot and at the surface is very inconspicuous. No sinking had been done on the vein and nothing of its true dimension could be learned. A drift north along the vein would soon enter the open valley side. More than likely the ore shoot will prove to be irregular in shape, because of its replacement character and also because the mineralization is apparently more or less localized in the sheared wall rock parallel to the main fissure. Other tunnels have been driven through the country rock and these have encountered minor stringers and fissures with sulphides, essentially of the same character as in the larger vein. Siderite occurs in one of the minor seams.

REGAL PROPERTY

The Regal group of claims lies at an elevation of 4,000 feet on the first tributary of Lightning Creek that flows off the west slope of Goat Mountain. The veins are exposed in the creek channel where the turbulent waters, falling over a series of cascades, have swept the bedrock clear. The stream at this point is perhaps less than two miles from Lightning Creek in air line, but it descends 1,400 feet before reaching the main valley. The veins had been known for some time and been prospected in a desultory fashion, but it was not until late in 1927 that, under the management of the Regal Mining Company, a road was begun up the nearly precipitous slope of Goat Mountain and active development started. The creek which tumbles over the veins hinders
work on them to some extent, but it can furnish sufficient power for the development.

The deposit has some unusual features, particularly in structure, for a steeply dipping vein, which trends in the direction of the stream, occupies the fissure with a lamprophyre dike and sends off mineralized bedded seams or branches. A number of such seams occur, but only two of them are large enough to be worthy of description. This unique deposit is in some massive quartzitic beds of the Prichard formation whose general trend is about N. 35° E. and dip 17° S.E.

The fissure vein strikes N. 40° W. and dips 55° to 65° to the northeast. It follows the lamprophyric dike for several hundred feet, but lower on the creek the dike swings more to the west and the vein continues without change into the quartzite. The vein occurs on both sides of the lamprophyre, which has the composition of minette, with particularly large plates of biotite in a very fine grained base. It also sends stringers into the dike or across the dike. For the greater distance the wide part of the vein is at the footwall side where it ranges from two inches to four feet, and is widest just below the junction of the bedded seams. The vein filling is pure quartz with scattered cubes of pyrite. It shows minor degrees of replacement of wall fragments, but its character is dominantly fissure filling.

The mineralization with sulphides is confined wholly to the bedded seams with deposition beginning at the crotch and continuing for a dozen feet or more between the bedding planes, but with decreasing quantity and thickness of sulphides and quartz. The sulphides consist of about half pyrrhotite and the remainder of sphalerite and galena with very minor but variable amounts of pyrite, arsenopyrite, and chalcopyrite. The usual sequence of deposition is shown with quartz first, and after a slight amount of fracturing followed by pyrite, arsenopyrite, pyrrhotite, sphalerite, galena, and chalcopyrite. The sphalerite is very black and has abundant rod-like granules of pyrrhotite arranged along crystallographic lines.

Several small sulphide seams leave the fissure from the hanging wall side, but the larger are on the footwall side. The upper vein on the footwall side strikes N. 35° E. and dips 17° S.E., exactly conformable with the bedding. This vein is eight inches thick where the sulphides creep in at the crotch, although immediately below the quartz vein is 16 inches wide. The bedded seam decreases to six inches in a very few feet, but the full limits of the vein were not disclosed. The second vein is perhaps less than 70 feet beneath the upper and it is exactly similar to it, although a little larger. Below the branch, the
fissure vein is about two feet wide, and above, it is two inches. The sulphides again occur at the turn and the width of the vein six feet from the fissure decreases to eight inches, and twelve feet away decreases to four inches. The mineral shoots of both the veins follow the junction of the bedded seams with the trunk fissure and so pitch into the hill at an angle of about 17°. Quartz and pyrrhotite predominate in the widest part of the shoots.

GOAT MOUNTAIN PROPERTY

The Goat Mountain property, whose veins outcrop on the part of Goat Mountain that forms the ridge between Lightning Creek and Cascade Creek about 2,000 feet above the valley floor, has been known and prospected for a number of years. Most of the early work was done on a camp and a long cross-cut tunnel from the base of the mountain along Lightning Creek in an attempt to explore a vein that crops about 2,000 feet above on the steep mountainside. More than 900 feet of tunnels were driven, but the attempt was unsuccessful, as only small unmineralized fault fissures and a narrow quartz vein were encountered. With the revival of interest in mining in 1926 and 1927 operations were again started by the Goat Mountain Mining Company, a new organization, and prospecting was transferred to the outcrop.

Both fissure and bedded veins occur on the property, with most of the sulphides in the bedded seams. The country rock is a particularly dense quartzitic facies of the Prichard formation with several thin sills of intrusive quartz diorite of pre-Cambrian (?) age. The veins, however, are in the quartzites, which are difficult and expensive to drill. The fissures approximately parallel the main Hope fault and have generally a quartz filling with scattered crystals of pyrite. The bedded veins are without gouge seams and they have apparently been formed by replacement along very minor slippage joints conformable with the bedding. The vein material consists mainly of quartz with granules or scattered masses of pyrrhotite, pyrite, sphalerite, and galena. The quartzitic wall shows hydrothermal alteration and in places contains disseminations of pyrrhotite.

At least six bedded veins, conformable with the bedding, and which strike N. 55° W. and dip 24° N.E. are exposed within a vertical distance of several hundred feet. These range from one to 10 inches in thickness and contain quartz with minor amounts of sulphides. A tunnel was being driven at the time the property was visited to intersect a two-foot fissure vein that showed considerable limonite in the outcrop. This vein, which strikes N. 45° W. and which dips 50° S.W., had
not been encountered in the tunnel, then in 200 feet, but its presence a short distance ahead was indicated by numerous small stringers with pyrrhotite and galena.

LUCKY STRIKE PROPERTY

The Lucky Strike veins are on the south slope of Goat Mountain at an elevation of about 4,000 feet along the first large tributary of Cascade Creek. The stream has a steep gradient and sufficient volume to provide ample power for mining purposes. The camp is reached by a well graded trail from the road at the base of the mountain. Several small tunnels have been driven on the property by the Lucky Strike Mining Company, one of them a crosscut which had not reached the veins.

Four veins have been discovered on the property, all of them of the fissure type and within the massive quartzite members of the upper Prichard. Below the outcrop the Prichard consists of a series of banded shales and quartzites cut by several lamprophyre dikes and a dioritic sill. The beds have been greatly disturbed by a system of minor faults, but they hold an average trend of N. 10° W. and a dip of 30° N.E.

The mineralization is like that on other parts of Goat Mountain and consists mainly of quartz and scattered grains or masses of sulphides composed of pyrite, pyrrhotite, sphalerite, chalcopyrite, and galena. In addition some of the veins have considerable calcite. As additional evidence of the high temperatures at which the minerals were deposited is the occurrence of biotite and hornblende in at least one of the veins. Sphalerite is next to pyrrhotite in abundance and it has an exceedingly black color. Marcasite is an interesting secondary mineral, for it replaces the pyrrhotite in concentric shells.

The vein highest on the mountain strikes N. 50° W. and dips 60° S.W. This one is about fourteen inches wide and is filled mainly with honey-combed quartz stained with iron oxides. A vein lower in the mountain has been prospected by tunnel for about 50 feet. This vein strikes N. 40° W. and dips 40° S.W. It is from eight to 10 inches wide and contains quartz with scattered grains and masses of sulphides.

PONDEROSA PROPERTY

The Ponderosa group of claims lies between the Goat Mountain group and the Lucky Strike property on the south slope of Goat Mountain and extends from the base of the mountain to near its summit. Little active work has been done on the property. Fortunately
the veins are well exposed on the steep, and, in many places, precipitous slope of the mountain and may be examined in the outcrop.

Both fissures and bedded veins occur. They are greatly similar to those on the adjoining claims and are in the same rocks. The fissure veins approximately parallel the Hope fault and strike N. 30° W. and dip steeply southwest with downthrow on the south side. The bedded veins are entirely conformable with the sedimentary formations and trend N. 45° W. and dip 20° N.E.

The mineralization is mainly quartz with scattered granules of pyrrhotite and galena, characteristic of both types of veins. In one of the fissure veins the galena and pyrrhotite is so intimately associated that the ore resembles that of the Blue Creek mine.

The bedded seams occur in the lower part of the mountain where they range from a fraction of an inch to 12 inches. Six of them are between six and 12 inches, but unfortunately the filling is mainly quartz. These show little swelling or pinching along the strike and dip. A short distance above the bedded seams is a fissure upon which some old cuts have been made. One of them follows a 12-inch bedded seam from which some pyrrhotite and galena have been removed, but it is soon cut off by the fissure which has crushed fragments of broken ore and country rock. The movement along the fissure was probably in part pre-mineral, but some of it continued later. Two fissure veins outcrop still higher on the mountain. These are roughly parallel and, at the surface, are about 10 feet apart. Both of them dip steeply to the south. The outcrops of both are honey-combed and contain scattered masses of galena in an ochreous yellow to red limonitic gossan. A short tunnel below the outcrop has cut the first of the veins. This is from one to two feet wide, only slightly smaller than the second vein, which lies to the north.

HOMESTAKE PROPERTY

The Homestake prospect lies at the base of Scotchman Peak in Sec. 29, T. 66 N., R. 3 E., several hundred yards north of the Hope fault on some cliffs of thick-bedded Prichard quartzite. The sedimentary beds have been considerably disturbed and show a drag against the Hope fault. The trend of the bedding changes from N. 10° E. to N. 40° E. near the Hope fault, but the dip remains about the same, 15° S.E.

The deposit differs from others on Goat Mountain in that the mineral is disseminated through a system of minor fractures and joint planes in the quartzite and not in bedded veins or fissures. The sulphide is mainly galena with only subordinate sphalerite. The galena
occurs in tiny seamlets one-eighth to one-half inch wide or in lenses one inch wide to three or four inches long, widely scattered through a zone several hundred feet wide. The galena also fills in and replaces the quartzite in certain small brecciated zones. Evidently the mineralizing solutions had no definite channels to follow and percolated through the minor fractures in the more or less shattered quartzite, diffusing the sulphides so widely that recovery will probably never be profitable. The galena and sphalerite are peculiarly free of quartz and other sulphides. Several tunnels have been driven into the mineralized zone, one of them about 140 feet long.

FULLGARTH PROSPECT

The Fullgarth prospect lies at the edge of Lightning Creek at the very base of Goat Mountain about one mile north of the Hope fault. The veins are within the border of the stock of granodiorite in the lower valley of Lightning Creek, along several joint planes in the igneous rock. These strike N. 80° E. and dip 70° S.E. The veins are about two inches wide and have a casing of hydrothermally altered rock on either side, the alteration indicated by bleaching of the granodiorite and the conversion of the biotite and hornblende to greenish chlorite and the dissemination of pyrite. Thin sections show that the feldspars have been altered to compact masses of sericite and that all the minerals have been cut by veinlets of calcite. The filling of these veins is mainly quartz and siderite (possibly ankerite or ferriferous dolomite) with a few scattered grains of galena, sphalerite, pyrite, and pyrrhotite.

DOUGHERTY PROSPECT

The Dougherty prospect lies far back in the Cabinet Mountains on the divide between the head of Lightning Creek and South Callahan Creek, about three-quarters of a mile northeast of Lake Darling. The prospect was probably first located in the latter part of the nineteenth century, but little work has ever been done on the property, which has been inadequately explored by several surface cuts and a shaft about 65 feet deep. The vein outcrop on the crest of the ridge on the Callahan Creek side, and the steepness of the slope below has left no room for an ore dump and what ore has been removed has slid to the creek about 700 feet below. The prospect is usually reached from the town of Clark Fork by a 22-mile trail along Lightning Creek, but it would be more conveniently reached from Troy, Montana. A logging railroad ends two miles below on Callahan Creek.

The vein is of the replacement fissure type and cuts quartzites and enters one of the pre-Cambrian (?) quartz diorite sills. Most of the
mineralization is in the quartz diorite, which apparently has been more susceptible to replacement than the quartzites. The vein is not far from the granodiorite stock that outcrops at Lake Darling and is very near two small porphyry dikes. The sill and the quartzites have been somewhat disturbed by the intrusion and the strike of the Prichard is locally N. 55° E. and the dip 45° S.E.

The mineralization is peculiar to the region, as the galena is accompanied by a gangue that includes garnet and epidote, minerals more characteristic of contact metamorphic deposits than of fissure veins. Other minerals are quartz, pyrite, and chalcopyrite, as well as hornblende and biotite from the sill rock. Pyrite is extensively developed in the wall and has accompanied rather widespread silicification. Studies of thin sections and polished surfaces of the ore indicate that the garnet and epidote were formed before the introduction of the sulphides, probably as the quartz was introduced.

The vein strikes N. 10° W. and has a dip of 62° S.W., which carries it into the ridge. It may be traced for several hundred feet along the edge of the ridge where the slope is so steep as to prohibit an overburden. The walls are fairly regular, but many fragments of diorite are included within the vein. The garnet is most abundant along the footwall in irregular bunches or pockets, which are more or less banded and which enlarge to as much as 10 inches. The main filling is with quartz and garnet but with galena distributed irregularly throughout. At the top of the shaft, the vein is about 45 inches wide and at the bottom is reported to widen to 62 inches. The width of the vein decreases in both directions along the strike, but it has not been sufficiently explored to determine its true limits or its possible value.

HAMMOND PROPERTY

The Hammond property is less than one-half mile from the Boundary County line along the North Fork of Grouse Creek in Sec. 4, T. 59 N., R. 1 E. It is in an area of Prichard rocks that is surrounded on all sides by granodiorite. The structure of the region is complex, as the sediments have been cut by several intrusion faults. These pass but a short distance from the property.

Two veins have been prospected on the property, the first by a tunnel about 800 feet long near the forks of the Creek about a mile above the Hammond home. The dump has some vein material consisting largely of quartz with minor amounts of pyrite, pyrrhotite, sphalerite, and galena. The sulphides clearly fill fractures in the quartz. At the portal, the vein is about seven feet wide, but this width includes
masses of broken country rock. The strike is nearly the same as the quartzites, which is N. 8° W. and the dip 60° N.E. A second vein lies about one-half mile to the north with outcrop in the creek. The portal was at the foot of a waterfall and was inaccessible because of high water when the property was visited. The vein follows the strike of the quartzites in a narrow brecciated zone, which shows hydrothermal alteration and contains scattered crystals of pyrite. The tunnel is reported to be 175 feet long.

WALTER PROSPECT

The Walter prospect is on some small bedded veins about half way up the steep south slope of the Cabinet Mountains about one and three-quarters miles northwest of the town of Hope. The country rock is thick bedded, massive quartzite, slightly micaceous, belonging to the Prichard formation. The veins follow the bedding, which has a trend of N. 10° E. and a dip of 32° S.E., and range from two to eight inches wide. One vein is reported to swell to three feet in one place. The vein filling is mainly quartz, which has been shattered and the fractures partially sealed by scattered grains or granules of pyrite, sphalerite, and galena. A faint ribbon structure has been in part produced by the shattering of the quartz and the subsequent introduction of the sulphides in the fractures parallel to the walls of the veins. A crosscut started a short distance below the outcrop had not reached the objective when the property was visited.

Many other veins of like character may be found in the region surrounding Hope, some of them prospected in the early days and long since abandoned.

KOOTENAI PROSPECT

A discovery in May, 1928, was reported on the west side of Kootenai Point on the shore of Pend Oreille Lake about four miles northeast of Sandpoint. Flood waters of the lake later covered the disclosure and nothing could be learned of its size or value. Specimens reported to have been collected at the deposit contain mainly magnetite and pyrite with some galena, and associated with quartz, calcite, and epidote. Part of a hydrothermally altered granodiorite wall containing considerable epidote and pyrite remained attached to a piece of the magnetite. The deposit probably occurs in the body of granodiorite or granodiorite porphyry that forms a part of Kootenai Point and may possibly occur as a replacement of the granitic rock along a fissure. Extensive development of this deposit has been undertaken.
COPPER DEPOSITS

COPPER GIANT PROPERTY

The Copper Giant property has been in existence much longer than most other properties in the district and consequently has been more fully explored. The total development amounts to about 1,300 feet of underground workings and several open cuts. Most of this work has been on a single vein. Some copper has been mined from it and stored on the dump, but none has been shipped.

The Copper Giant lies on the south slope of Howe Mountain near the main improved highway about three miles west of Clark Fork and is one of the most easily accessible properties in the district. Several of the veins outcrop near the road at the foot of the mountain, but the main exposure lies several hundred feet higher on the mountainside.

Of the several veins, only the Copper Standard has been adequately explored. All follow fissures which they have enlarged to greater or less extent by replacement. The fissures on this property occur in two pronounced sets, the most prominent trending to the northeast with steep dip to the southwest. One of the northwest set is joined by several from the northeast. The veins have pronounced outcrops and some of them have been traced for long distances. They are in the greenish shales, some of them laminated, and the limy quartzites of the Wallace formation. The quartzitic rocks are prone to develop rather clean-cut fractures, but the thin bedded shales are reduced to impervious clays along fault planes and the veins play out or break up into stringers upon entering rocks of such character. The sedimentary beds strike about N. 50° E. and dip 50° E.

The chief sulphide mineralization has been by chalcopyrite accom- panying by very subordinate amounts of pyrite, the latter usually shattered and partially replaced by the chalcopyrite. The gangue minerals include quartz, ankerite or ferriferous dolomite. These minerals are clearly the products of three fairly distinct stages of mineralization. Secondary enrichment has been negligible and only minor amounts of incipient chalocite along with small patches of malachite occur in the outcrop with the primary sulphides.

The Copper Standard vein is the longest and most persistent on the property and may be traced to the top of the mountain from the base, where it is known as the Grand Copper vein. The vein has a curved course and the strike varies from N. 40° E. to N. 55° E. and the dip from 73° to 75° N.W. Most of the development has been about half way up the mountain where the vein has been explored by a main
tunnel 570 feet long and several shorter tunnels. In the main tunnel, the vein was encountered 200 feet from the portal and followed for 280 feet before cutting the main ore shoot and then extended 110 feet beyond where the vein disappeared by subdivision into the soft shales. The vein has a seam of gouge along either wall. In general, the walls are sharp but in some places the regularity has been partially destroyed by replacement of the wall by the carbonate gangue. Inclusions of country rock showing various degrees of replacement are common in the vein and in some parts form a large part of the vein matrix. The vein commonly pinches and swells along both strike and dip. For most of the distance it is about one foot wide, and, to where the main ore shoot is reached, is composed mainly of barren quartz. At the main ore shoot, the vein widens so that for some distance it is two to three feet wide. The ore shoot is about 60 feet long on the strike of the vein and has most of the chalcopyrite in the hanging wall. Some of the chalcopyrite is irregularly scattered in small bunches through the vein, but for about 30 feet the vein has eight to 12 inches of nearly solid chalcopyrite that is frozen to the hanging wall. The shoot has been explored by a raise that extends about 30 feet above the tunnel, with copper showing the entire distance. A small drift started at the top of the raise followed the shoot for about 30 feet and then pulled into the hanging wall and by so doing lost the vein. Chalcopyrite is exposed for about 20 feet. A shaft was also sunk on the vein to a depth of 30 feet, but, because it was filled with water, could not be examined. It is reported to show chalcopyrite to the bottom, but distributed through an increasing thickness of vein matter. Another small shoot was also exposed in the upper workings, but this apparently failed to show much chalcopyrite, if any, in the main tunnel.

Another vein, the King Bolt, lies about 600 feet east of the Copper Standard and is parallel to it. This vein where exposed in several small cuts is about 20 feet wide, but is apparently without sulphide mineralization, at least on the surface.

Several intersecting veins have been prospected near the base of the mountain. The principal vein strikes N. 43° W. and dips 50° S.W. It shows scattered sulphide mineralization for the 90 feet it has been explored. This vein is from 18 to 40 inches wide and shows repeated opening by movement along its plane, some of the movement post-mineral. The vein has several parallel stringers and it is also joined by a vein that strikes N. 40° E. The second vein consists of from 12 to 30 inches of barren quartz and lacks the mineral and post-mineral shattering of the first. Similar relationships are shown in several other
nearby veins. Some of them are sparsely mineralized. A description of them would involve merely a repetition of what has been said of the others.

**CLARINDA PROPERTY**

The Clarinda is also one of the old copper properties that has been sporadically developed for many years. The early work was done on the outcrop by cuts and tunnels, the most important of which is known as No. 3 tunnel. Later, under the management of the Clarinda Copper Mining Company, the work was transferred to a long crosscut from the base of the mountain, which was to tap the vein at depth, but the effort ended in disappointment, for after 2,100 feet of tunneling the fissures showed little signs of mineralization. Work since then has been generally abandoned.

The Clarinda group adjoins the Copper Giant on the east and is less than three miles from Clark Fork. Veins are much less numerous and persistent on the Clarinda than on the Copper Giant and only two have been uncovered, and, of these two, only one, the Lone Pine, has been deemed worthy of exploration. This is of the fissure type, which in many ways is similar to the Copper Standard vein on the Copper Giant property. It has a strike of N. 45° E. and a dip of 68° N.W., and contains two rather widely separated shoots of unlike mineralization. The country rock is the Wallace formation, probably in its upper part, and consists mainly of greenish shales and quartzites with a few limy members. The prevailing strike is N. 10° E. and the dip 50° S.E., but in the proximity of the vein the bedding in many places is considerably disturbed by the upthrust movement along the fissure. The vein lies about a quarter of a mile west of the Packsaddle fault where it crosses Howe Mountain.

The Lone Pine vein has an interesting mineralization, inasmuch as one of the small shoots contains small granules of galena with much the same relationships as in some of the lead-silver veins. In the other shoot, the chief copper mineral is chalcopyrite, associated with a gangue composed of quartz and ankerite or ferriferous dolomite. The chalcopyrite usually occurs in lenticular masses or bands several inches wide parallel to the walls or as scattered grains, all shattered by the subsequent movement along the vein and cemented and in part replaced by the younger stage minerals, principally carbonate, but including a little quartz, galena, and tetrahedrite. Some of the bands of ankerite and dolomite are several inches wide and these range down to minute seams. The galena occurs as scattered masses and as crystals less than a quarter of an inch in diameter in the pore spaces of the early brecciated vein
filling. A single tiny seam of tetrahedrite (freibergite) was found associated with the last stage quartz, which cuts a specimen of chalcopyrite and ankerite or ferriferous dolomite. The youngest stage quartz is fairly abundant in this deposit. The secondary minerals at the surface are not worthy of mention.

The Lone Pine vein is most fully explored in the No. 3 tunnel, where it has been opened for 400 feet in a tunnel 520 feet long. The vein near the portal of the tunnel has tight walls and is composed of barren quartz with some fragments of hydrothermally altered wall rock. Inward the vein becomes more broken and at the face of the tunnel is greatly shattered. The vein ranges from one to four feet wide, most of it barren of sulphides. The first shoot contains galena, which occurs as scattered crystals and granules in a very porous vein filling consisting of shattered, friable fragments of early vein quartz with a few scattered grains of chalcopyrite only partially sealed by the solutions which deposited the later carbonate and quartz. This shoot is less than 20 feet long on the strike of the vein. Its length on the dip is unknown. The second mineralized shoot lies 200 feet beyond. It has a length of 15 to 20 feet along the strike and contains irregularly scattered bunches or pockets of chalcopyrite. The shoot is about 12 inches wide. A raise passed out of the ore less than 20 feet above the tunnel level and a 75-foot shaft passed through the ore in less than 50 feet. A fault, which is probably pre-mineral with some post-mineral movement, lies about four feet from the Lone Pine vein in the hanging wall. It dips somewhat steeper than the vein and probably joins it with depth. In the face of the tunnel the rock, which is the thin bedded, shaly member of the Wallace formation, is greatly shattered and the vein disappears by pinching after passing into a pulverized or ground quartz wedge.

The vein is also explored 325 feet below the No. 3 level by the long cross cut No. 5 tunnel, which was driven in 1,545 feet to the vein and thence about 600 feet along it. The fissure is entirely barren of a vein filling, although it shows minor amounts of hydrothermal alteration. It has the same strike and dip as in the higher level, but the ground has been shattered through a zone seven to eight feet wide and changed to gouge, which has prevented the entrance and passage of mineralizing solutions. A concrete bulkhead prevented a full examination of the vein.

Carpie Property

The Carpie under the ownership of the Carpie Mining Company is another copper property that has been prospected for many years.
Development has consisted mainly of a shaft 300 feet deep with four levels from which drifts ranging from 20 to 170 feet long have been driven. The plant is equipped with a steam-driven hoist and compressor. Up to the time of the writer's visit little work had been done on the property other than necessary maintenance since 1921.

The Carpie property lies on the north bank of the Clark Fork directly across from the railroad station at Cabinet. It may be reached by either ferry or footbridge. The surface workings are about a hundred feet above water level and about a hundred yards from the shore. Water stands in the shaft to within 135 feet of the surface and this corresponds to the water level in the river.

The mineralization has been confined to a single shoot in a vein that is remarkable for its great length. The vein is mainly siliceous and because of its superior resistance to erosion may be traced for more than a mile from the river northward entirely across the low hill, which bounds the Cabinet gorge, to the alluvium-covered flat south of Sugar Loaf Mountain. For most of the distance the vein forms a prominent ledge from 10 to 20 feet wide and in some places equally as high. Throughout its length it is identified as a vein quartz breccia, partially to wholly cemented by a reddish jasper. This vein is within the Striped Peak formation whose prevailing strike is N. 20° W. and dip 18° N.E., but locally the bedding has been disturbed by many faults of slight displacement. The vein strikes N. 40° W. and dips 75° S.W. The country rock consists chiefly of thin-bedded, flaggy, greenish shales and sandstones with many reddish members.

The mineralization in the Carpie shoot is interesting, inasmuch as it is clearly the product of at least five stages of deposition. A list of these minerals includes pyrite, chalcopyrite, and tetrahedrite as sulphides; in a gangue of quartz, jasperoid quartz, ankerite or ferriferous dolomite. Quartz accompanies every stage, but the other minerals were deposited within certain definite periods, as described elsewhere. The tetrahedrite is not abundant and apparently adds but little to the value of the deposit.

Near the shaft the vein is 12 to 14 feet wide, but on the 300-foot level it is reported to decrease to six feet. Along the strike, however, the width remains remarkably constant, although except in this one place it carries no sulphides. A gouge seam two to 10 inches wide lies along the hanging wall at the surface, but it alternates along either wall with depth. The vein holds many small inclusions of wall rock and is typically a vein breccia whose most noticeable feature is the shattered early vein quartz and jasperoid filling. The fragments of early white
quartz range from a fraction of an inch to three or four inches. Subsequent movement has broken the quartz and its reddish jasper cement to much larger blocks and produced much larger openings which have not been entirely filled by the younger minerals.

Chalcopyrite occurs at the surface showing only incipient stages of secondary alteration. Little is known of the vein underground, as the shaft was nearly filled with water at the time of the writer's examination. The first drift at 70 feet has been boarded off. The second drift at the 100-foot level follows the vein for about 40 feet. At this level the sulphide is reported to be mainly pyrite. A drift on the 200-foot level has explored the vein for 170 feet and some chalcopyrite and a little tetrahedrite are reported. The highest grade ore was reported from the 300-foot level, where the vein was drifted on for 147 feet.

**ALAMO PROSPECT**

The Alamo prospect lies on the west slope of Howe Mountain about one-half mile east of Denton Siding. The vein is crossed by the highway, but shows no sulphides except in a small shoot several hundred feet above. The vein is rather easily traced at the surface and it is explored by several cuts and a tunnel.

This vein fills a fissure that trends N. 85° E. and which dips 75° N.W., although in some places the dip is vertical and even steeply to the south. For part of the distance the fissure is also occupied by a lamprophyre dike. The country rock is the upper St. Regis formation consisting mainly of thick-bedded, white and greenish quartzites interspersed with thin beds of reddish and purplish, laminated shale and sandstone. These beds strike N. 10° E. and dip about 62° S.E.

The mineralization in this vein differs from that in the neighboring copper deposits in that the deposition has occurred in essentially a single, although somewhat interrupted, stage and the list of minerals includes specularite and magnetite in addition to quartz, pyrite, chalcopyrite, galena, and carbonate. The sequence of deposition has been discussed elsewhere and need not be repeated. Specularite or specular hematite is the most abundant of the vein minerals except the quartz, although locally the latter may predominate. It occurs in long tabular crystals or plates as much as an inch long intergrown with the quartz and usually mixed with minor amounts of magnetite. The chalcopyrite is scattered through the hematite ore in small masses and is in some places accompanied by small grains of galena. The carbonate gangue is not abundant and forms a very minor part of the filling. Most of the
pyrite occurs in a shoot by itself. Secondary alteration at the surface has produced minor quantities of chalcoite and covellite, some of it stained with malachite.

The vein is tabular, but swells and pinches both along the strike and dip. Most of it is composed of quartz with a few angular and rounded inclusions of country rock. In the hematite and chalcopyrite zone the inclusions of both lamprophyre and sedimentary rock are converted largely to greenish chlorite. An altered zone also incases the vein for several inches on either side. The vein has no open cavities or clefts and shows little brecciation by mineral or post-mineral movement. Diverging stringers in some places are numerous as well as some intersecting veins and parallel seams. The vein is about one foot wide in the road-cut, but farther up the hill where it has been opened by a small cut consists of eight feet of barren quartz. The main mineral shoot has been followed by a tunnel about 125 feet long, disclosing here and there small patches of specularite and chalcopyrite. The shoot ranges from two feet to six feet wide. A 10-inch seam with large bladed crystals of specularite joins the vein near the portal at approximately right angles.

**BUMBLE BEE PROSPECT**

The Bumble Bee is an old prospect that has been relocated a number of times. Most of the workings are old and were inaccessible at the time of the writer’s visit, but later in the year the tunnels were cleaned out and retimbered preparatory to further prospecting. This property lies about two and one-half miles above the mouth of Johnson Creek in the down-faulted block of Striped Peak formation a few hundred feet west of the Packsaddle fault. The bedding of the formation strikes N. 35° E. and dips 42° S.E., but the vein was not seen in place and its direction and dip remain unknown.

Some recent work had been done on a mass of talus and landslide material along the creek where many large blocks and boulders of vein matter have been carried down from higher up the mountain. This float consisted mainly of ankerite or ferriferous dolomite, with minor quantities of chalcopyrite, pyrite, quartz, and scattered grains of galena. Several hundred feet of tunnels were needlessly driven through the talus in search of the vein. In one place the tunnels passed into greatly faulted bed rock, perhaps into the Packsaddle fault zone.

The old workings, unknown to the writer at the time of his visit, were some distance up the mountainside. A tunnel is reported to have been driven along the vein, which ranges from one to four feet wide for 600 feet, gaining a depth of about 300 feet. Specimens collected along
the vein and sent the writer contain scattered grains and masses of chalcopyrite associated with shattered pyrite crystals and variable amounts of quartz and carbonates. The mineralization is essentially the same as at the Copper Giant property across the river and shows the same number of stages and the same list of minerals introduced in each stage. Tetrahedrite is the only additional mineral and it was introduced in very small amounts in the last stage along with quartz. Most of the specimens submitted, taken at different points along the tunnel, show stages of oxidation and are generally stained with limonite and malachite.

GOLD DEPOSITS

AUXER PROPERTY

The Auxer property, owned by the Auxer Gold Mines Company, lies at the head of the west branch of Wellington Creek about three and one-half miles northeast of Hope. This property is in one of the glacial cirques that clusters on the north side of the southernmost ridge of the Cabinet Mountains at an elevation between 5,000 and 6,000 feet. Because of the high altitude the snow is deep in winter and lingers late into the spring and summer. The topography is rugged and the vegetation light, although sufficient timber exists for mining purposes and for raising steam for power. Wellington Creek in its lower course has sufficient volume for the development of electrical power should the mineral disclosures justify the construction of such a plant. Development has continued over a long period of years and at the time of the writer’s visit had approximated 1,300 feet of underground workings, nearly half of it in a long cross-cut tunnel that still lacked considerable distance from cutting the vein which shows at the surface. This property is reached by trail from Hope.

Several veins have been found on the property, but only one has given sufficient promise to warrant present exploration. This vein is in a thick quartz diorite sill of pre-Cambrian (?) age and is a replacement along a fissure that strikes about N. 28° E. and dips 55° S.E., trending in the same direction as the sill. The other veins are also within the diorite sill, and all of them are in fissures of only minor displacement but of sufficient movement, however, to cause some gouge. The walls show variable amounts of hydrothermal alteration and the feldspars and hornblende have been converted to sercite, epidote, and chlorite, sprinkled with pyrite.

The mineralization of the vein has been mainly by pyrite in a quartz gangue, but locally the pyrite is accompanied in very subordinate amounts of galena, sphalerite (?), chalcopyrite, and tetrahedrite (?),
and in addition calcite and siderite. The gold is reported to be mainly with the pyrite but shows some increase with the galena. Selected sample of the ore are reported to assay from two to 17 dollars in gold, the average near five.

Little was seen of the principal vein at the time the property was visited, for the 65-foot shaft, which represents the main development, was nearly filled with water. The vein may be traced for a short distance along the surface where it ranges from three to four feet wide. Near the bottom of the inclined shaft it is reported to widen to eight feet. This vein and the others show little regularity in width, but pinch and swell along both strike and dip, the pinching invariably accompanied by an increase in the thickness of the gouge band. The long cross cut from a deeper part of the cirque has been started about 100 feet lower than the outcrop. Several small veins and stringers were encountered in the crosscut, one of them about 30 inches wide but unmineralized with sulphides. This has many small stringers.

**BONNER PROPERTY**

The Bonner property lies high on the north slope of the valley of Trestle Creek about two miles from its mouth. The valley slope is very steep and the camp of necessity has been placed several hundred feet below the outcrop and tunnels. Water is scarce and has been piped in from springs higher on the ridge. The property has been extensively prospected by two tunnels, one 200 feet long and the other 1,650 feet long.

The vein is mainly a filling of a fissure, but this process has been accompanied by replacement. The vein occurs wholly within the Frichard formation, which has been considerably shattered and faulted from the force of the granodiorite intrusion that lies on the opposite side of the ridge. Several intrusion faults of considerable magnitude occur nearby, and several porphyry dikes and lamprophyres outcrop in the vicinity of the vein. One of the lamprophyres is reported to cut the vein. The vein has a general trend of N. 15° E. and a flattened dip to the east, ranging from 30° to nearly horizontal. The quartzitic wall rock has been hydrothermally altered and has sericite, chlorite, biotite, and disseminated grains of pyrite and pyrrhotite in it.

The principal vein filling is quartz and it is accompanied by variable amounts of pyrrhotite, the most abundant sulphide, and lesser quantities of pyrite, sphalerite, galena, chalcopyrite, calcite, and feldspar. These are essentially the products of a single stage of deposition whose general sequence has been given elsewhere. Calcite occurs in large
rhombohedral crystals in certain parts of the vein only. The tenor of
the ore is unknown. The chief content is reported to be gold, but
its associations were not determined. Some of the pure pyrrhotite was
assayed for gold and silver, and was found to contain neither.

The vein is very irregular in form, swelling and pinching in both
strike and dip and changing its direction as well. Consequently the
tunnel along it is exceedingly crooked, in fact more crooked than was
necessary. The vein ranges from 18 inches to five feet wide, but the
average is between three and four feet. It has been followed for about
550 feet in the lower tunnel and then lost because of faulting. Through-
out this distance it carries uniformly distributed amounts of sulphides.
The vein is everywhere frozen to the walls and has no gouge except
where disturbed by post-mineral movement. For the first 150 feet
the vein ranges from 20 inches to four feet and is then lost against a
fault which trends N. 5° W. and dips 80° E. This fault has a reverse
character and the hanging wall was raised more than a dozen feet. The
vein was again encountered about 50 feet to the east where the dip
brought it back to the tunnel level. The vein was then followed for
about 430 feet and again lost in a reverse fault with a northerly trend
and 60° dip to the west. For this distance the vein ranges from three
to five feet and is well mineralized with pyrrhotite. In an endeavor to
pick up the vein, more than a thousand feet of tunnels were driven, one
a long, semi-circular tunnel, which is apparently everywhere under the
vein, and another in direct alignment with the main tunnel but every-
where above the other segment of the vein. Several small veins were
cut in the search, one of them two to three feet wide and filled mainly
with calceite.

KING SOLOMON PROPERTY

The King Solomon property lies about a mile and a half above the
mouth of Trestle Creek and adjoins the Bonner property on the west.
This property may be reached by automobile over a steep road that
mounts to the top of a terrace on the north side of the Trestle Creek
Valley. The development work on this property consists of a tunnel
more than 900 feet long.

The veins on this property are within a quartz diorite sill that has
been extensively sheared and faulted in zones trending northwest and
northeast. Movement on each of the faults has been slight, but has
been sufficient to cause heavy zones of gouge. The mineralization
occurs in narrow lenticular quartz veins and stringers which range from
one inch to one or two feet wide. These occur as a series of lenses, more
or less completely isolated, along the fissures. The minerals which have
been identified are quartz, pyrite, pyrrhotite, chalcopyrite, and calcite, but excepting quartz none of them are abundant. The gouge as well as the wall has been hydrothermally altered and changed to aggregates of sericite, chlorite, biotite, albite, and calcite, accompanied by silicification and the introduction of pyrite. The deposition of minerals has been in part by replacement, but also by filling of irregular openings in the plane of the fissure.

The tunnel follows for the greater part of its course a sparsely mineralized fissure which trends N. 45° W. and dips steeply to the northeast. The fissure contains a quartz vein from 12 to 18 inches wide and about 40 feet long where encountered in the crosscut, but the vein disappears inward in a heavy gouge zone. It was followed for 400 feet more, but for most of the distance the fissure contains nothing but gouge, which is as much as five feet thick in places, and with recurrent small quartz lenses and stringers a few inches wide. Inward the dip of the fissure changes to vertical and finally to 85° W. Several crosscuts driven to both sides of the main tunnel have exposed a number of other fissures, some of them parallel to the main fissure and some of them at right angles to it. All of them contain minor seams and stringers of quartz. Tunnels driven in any direction on this property are prone to expose many fissures more or less ineffectively mineralized.

McWilliams Property

The McWilliams property lies at the base of Goat Mountain about three and one-half miles northeast of Clark Fork and several hundred yards north of the Hope fault. Several veins have been prospected. These range from 10 to 20 inches wide and are composed essentially of massive quartz that has been shattered and the fractures partially healed by minor amounts of pyrite and arsenopyrite. The veins are within some dark gray massive quartzites of the Prichard formation, which, near the veins, show hydrothermal alteration with dissemination of pyrite. The development has been by three tunnels, two of them about 140 feet long and one about 70 feet. In one of the tunnels the vein is from 10 to 20 inches wide and trends northwest and dips steeply to the southwest. In another tunnel the vein is 20 inches wide in the bottom, but branches upward. A showing about one-quarter of a mile to the west contains galena.

Eagan Prospect

The Eagan prospect is about four and one-half miles above the mouth of Trestle Creek on the north side of the valley. Several quartz veins lying between the bedding planes of the massive quartzite mem-
bers of the Prichard formation have been explored. These are essentially fissure fillings of massive quartz with scattered cubes of pyrite and occasional grains of galena. The veins and bedding strike N. 20° E. and dip from 15° to 18° S.E. Development has been by two tunnels and an incline. The lower tunnel is 480 feet long and cuts two veins, the first about three feet wide and the second, which lies about 80 feet beyond, about 18 inches wide. Both contain scattered grains of galena and striated cubes of pyrite, some of them one-half inch square. A minor amount of siderite or probably ferriferous dolomite also accompanies the galena. Both veins have tight walls without gauge and were cut incidentally to driving the tunnel to intercept a third vein which outcrops near the top of the ridge and said to carry galena.

Further development higher on the ridge has been mainly along an incline from the outcrop. At the mouth of the incline the vein is a lenticular mass about four feet wide, but it pinches to a few inches along the strike in both directions. Pyrite is particularly abundant and occurs mainly in vugs or pockets, some of them disk-shaped and from four to six inches long. It also occurs in lesser amounts along the vein as disseminations. Along the dip the vein averages two to three feet wide and carries pyrite and scattered grains of galena.

**PATTEN PROSPECT**

The Patten prospect lies about six miles above the mouth of Trestle Creek on a small tributary that enters from the south. Only the outcrop could be examined as the crosscut from below had not reached the vein. The vein is about eight feet wide at the surface and strikes N. 42° W. and dips 75° S.W. It cuts both quartzite of the Prichard formation and a quartz diorite sill. It maintains its thickness for a remarkably long distance.

The vein is composed almost wholly of calcite, but has some quartz and siderite, and scattered grains of sulphides including galena, pyrrhotite, and possibly smaltite. The vein also has patches of greenish to brown tourmaline crystals that are associated with the quartz. The surface workings are moderately stained with oxides of iron and manganese, including limonite and pyrolusite. Pinkish crusts of erythrite or cobalt bloom coat some of the surfaces of the outcrop and fill fractures in the vein. It is probably the oxidation production of the smaltite (?).

**CAMPBELL PROSPECT**

The Campbell prospect, one of the oldest in the district, was relocated in 1927. This prospect lies a few hundred yards north of the Hope fault about one and three-quarters miles northeast of Denton.
Siding at the base of the Cabinet Mountains in Sec. 9, T. 56 N., R. 2 E.
As little work has been done in recent years, the prospect is difficult to
examine. Timbers that were installed shortly before the writer's visit
had failed to prevent the tunnels from caving at the portals.

The mineralization occurs in a shear zone in an altered lamprophyre
stock whose composition is that of minette. The shear zone trends
about N. 70° E. and has a steep dip to the northwest. The rock has
been intensively altered by hydrothermal solutions and where the min-
eralization has been greatest is converted to a green chloritic schist.
The mineralization has been mainly in pyrite, which has apparently
replaced the schist direct without extensive silicification. The pyrite
occurs in cubical and massive forms. In one of the mineralized shears,
the pyrite is accompanied by small quantities of chalcopyrite, galena,
and sphalerite. The shearing movement extends through a zone prob-
ably as much as a hundred yards wide, but only parts of it have been
mineralized.
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