DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

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**PROFESSIONAL PAPER 62**

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# THE

# GEOLOGY AND ORE DEPOSITS

OF THE

# CŒUR D'ALENE DISTRICT, IDAHO

BY

FREDERICK LESLIE RANSOME

AND

FRANK CATHCART CALKINS



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WASHINGTON
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# THE GEOLOGY AND ORE DEPOSITS OF THE CŒUR D'ALENE DISTRICT, IDAHO.

By Frederick Leslie Ransome and Frank Cathcart Calkins.

## INTRODUCTION.

By F. L. Ransome.

### LOCATION AND AREA OF THE DISTRICT.

The area commonly known as the Cœur d'Alene district (although for purposes of record and administration it has been divided into a number of local mining districts) is situated, so far as its productive part is concerned, in Shoshone County, in that narrow portion of Idaho which extends northward between the States of Washington and Montana to the international boundary. It lies almost entirely upon the western slope of the Cœur d'Alene Mountains,[a] a broad and rather complex member of the North American Cordillera.

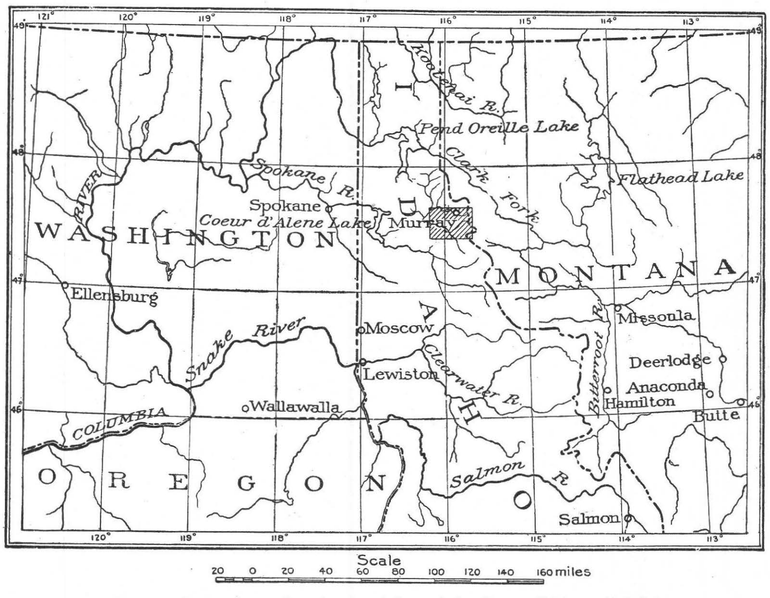


Fig. 1.—Index map showing position of the Cœur d'Alene district.

The area shown on the Cœur d'Alene special map (Pl. I, in pocket), embracing the quadrangular tract of country that forms the particular subject of this investigation, lies between the meridians of 115° 40′ and 116° 10′ west longitude and the parallels of 47° 25′ and 47° 40′ north latitude. It covers an area of 404 square miles. The position of this tract, which was mapped by Mr. Van H. Manning, topographer, in 1900–1901, on a scale of 1:62,500, or approximately 1 mile to the inch, is indicated on the accompanying index map (fig. 1). Although a

[a] This group of mountains is on most maps made a part of the Bitterroot Range. Lindgren has suggested, however (Prof. Paper U. S. Geol. Survey No. 27), that it would be better to restrict the name Bitterroot to the range separating the waters of Bitterroot and Clearwater rivers and forming a southern continuation of the Cœur d'Alene Mountains south of the vicinity of Lolo Pass.

few mines and prospects lie just outside of its borders, it will be convenient and sufficiently accurate to refer to the mapped area in the following pages as the Cœur d'Alene district.

The district lies south of the main line of the Northern Pacific Railway, but is reached by a branch of that railway from Missoula, Mont., and by a branch of the Oregon Railroad and Navigation Company from Tekoa, Wash., about 35 miles southeast of Spokane. Both roads connect at Wallace, the principal town of the district and the seat of Shoshone County.

## FIELD WORK AND ACKNOWLEDGMENTS.

Geological field work in the Cœur d'Alene district was begun by Mr. F. C. Calkins in July, 1903. Assisted by Messrs. W. A. Williams and D. F. MacDonald, he continued in the field until October. The senior author of this report visited the district for a few days in August and made preliminary examinations of some of the mines; but the main results of the first season's work were the subdivision of the thick series of pre-Cambrian sediments into stratigraphic units and the mapping of a large part of the area by Mr. Calkins and his assistants.

Work was resumed in the summer of 1904, Mr. Calkins, assisted by Mr. MacDonald, completing the geological mapping of the area, while Mr. Ransome, assisted by Mr. Edward R. Zalinski, studied the occurrence of the lead-silver, copper, and gold ores.

A preliminary report [a] on the results of the two seasons' work was published in 1905. Various causes, however, have unavoidably delayed the appearance of the final report, and consequently descriptions based upon observations made in 1904 do not in all cases fully represent the mining industry in its present condition. Although an effort has been made to bring the information regarding mine developments and production up to the end of 1906, yet the reader should remember that the report as a whole is based on what could be seen and learned of the ore deposits in 1904.

With one exception all of the mining companies have permitted free access to their maps and have willingly furnished such information as was asked for. Among those to whose courteous cooperation the work is particularly indebted are Mr. Stanly A. Easton, general manager of the Bunker Hill and Sullivan Company; Mr. W. Clayton Miller, general manager of the Federal Mining and Smelting Company; Mr. Joseph Kean, who in 1904 was operating the Granite, California Consolidated, and Sixteen-to-One mines; Mr. James F. McCarthy, manager of the Hecla mine; and Mr. Thomas L. Greenough, formerly one of the owners of the Morning mine. Acknowledgement is due also of the professional courtesies extended to us by Mr. J. M. Porter and Mr. C. F. O. Merriam, mining engineers; of the abundant historical material supplied by Mr. Adam Aulbach, of Murray; and of the storage facilities generously afforded by the Cœur d'Alene Hardware Company, of Wallace. If the friendly services of the many mining men who willingly devoted hours to our guidance underground must be recorded without individual acknowledgment, this necessity by no means indicates any lack of appreciation of the value of their assistance. A general report on the ore deposits of any district inevitably owes much to the local knowledge, veracity, and willing cooperation of the men who are engaged in the actual work of mining.

## OUTLINE OF THE GEOGRAPHY AND GEOLOGY OF NORTHERN IDAHO AND ADJACENT PARTS OF MONTANA AND WASHINGTON.

### INTRODUCTION.

Our knowledge of the topography and geology of northeastern Washington, northern Idaho, and northwestern Montana is as yet far from satisfactory. The greater part of this region consists of rugged or densely forested mountains, is very sparsely settled, and is poorly provided with roads and trails. The best general maps obtainable have many inaccuracies and are greatly wanting in detail.

[a] Ransome, F. L., Ore deposits of the Cœur d'Alene district, Idaho: Bull. U. S. Geol. Survey No. 260, 1905, pp. 274-303.

In recent years Lindgren [a] has thrown much light on a region some 12,000 square miles in area whose northern border lies about 30 miles south of the Cœur d'Alene district; Daly [b] has performed a similar service for a strip of country along the international boundary and has also published important papers on the nomenclature of the mountain ranges,[c] and on the contact phenomena of certain intrusive sheets of gabbro in the northeastern corner of Montana;[d] Willis [e] has worked out the general stratigraphy and structure of the Lewis and Livingston ranges; and Walcott[f] has reviewed and correlated the Algonkian formations from the Belt Mountains into northeastern Idaho.

In 1905 Mr. Frank C. Calkins supplemented the detailed work of the preceding season in the Cœur d'Alene district by a reconnaissance northward from Cœur d'Alene Lake and eastward to Flathead River. The results of his investigation, which had for its main object the correlation of the Cœur d'Alene sedimentary series with those described by Daly along the northwest boundary and by Willis in the Lewis and Livingston ranges, will be published by this Survey as a bulletin. The following outline of the general geographical and geological features of the region is based on all the sources of information just mentioned and on personal observations, made in connection with the study of the Cœur d'Alene district, as well as in the course of a reconnaissance along the northwest boundary from Porthill, Idaho, westward to Lake Osoyoos, Washington, and in a trip on foot along the Northern Pacific Railway, from Wallace, Idaho, to Missoula, Mont.

## OROGRAPHY.

Along the international boundary the mountainous complex making up the North American Cordillera, although varying much in general altitude, extends practically unbroken from the main front of the Lewis Range, overlooking the Great Plains of Montana, to the Pacific Ocean. The most satisfactory divisions and nomenclature of this mountain complex are those proposed by Daly. Fig. 2 is based mainly on an outline map accompanying his paper.[g] The great interior plateau of British Columbia may perhaps be considered as extending for a few miles south of the boundary, down Okanogan River, but the plateau feature is here neither so distinct nor so extensive as to constitute a notable exception to the prevalent mountainous topography. In the latitude of Spokane, however, which corresponds nearly with the northern edge of the Cœur d'Alene district, the great Columbia lava plain separates the Cordillera into two portions. On the west are the Cascade Range and Olympic Mountains; on the east a group of ranges forming part of what is commonly known as the Rocky Mountains. From the edge of the basalt plateau to the eastern front of the Cordillera the width of this mountain belt is about 200 miles. Although topographically its western boundary, owing to the contrast to the mountains afforded by the expanse of Columbia River basalt, is more conspicuous south of the latitude of Spokane than farther north, yet there is little difficulty in tracing a natural western boundary of the same mountain zone northward across the international line. This is afforded by a well-marked linear depression along which are distributed Cœur d'Alene, Pend Oreille, and Kootenai lakes and which is followed by Duncan River northward to its confluence with the Columbia near Donald, on the main line of the Canadian Pacific Railway. Daly has applied the name Purcell trench to this feature. (See fig. 2.) He describes its southern end, however, as lying at Bonners Ferry, on Kootenai River, whereas the depression is a notable feature in the topography of the country for 90 miles farther south, at least to the southern end of Cœur d'Alene Lake. Kootenai River in

[a] A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904.

[b] Summary Repts. Geol. Survey Canada for 1902 (pp. 136-147, 1903), 1903) pp. 91-100, 1904), and 1904 (pp. 91-100, 1905).

[c] The nomenclature of the North American Cordillera between the 47th and 53d parallels of latitude: Geog. Jour., vol. 27, 1906, pp. 586-606.

[d] The secondary origin of certain granites: Am. Jour. Sci., 4th ser., vol. 20, 1905, pp. 185-216.

[e] Stratigraphy and structure, Lewis and Livingston ranges, Montana: Bull. Geol. Soc. America, vol. 13, 1902, pp. 305-352.

[f] Algonkian formations of northwestern Montana: Bull. Geol. Soc. America, vol. 17, 1906, pp. 1-28.

[g] The nomenclature of the North American Cordillera, etc.: Geog. Jour., vol. 27, 1906, p. 588.

fact issues at Bonners Ferry from a relatively narrow transmontane gorge to flow northwestward in a broad valley, which also continues southward to Lake Pend Oreille and is followed by the Great Northern Railway. No main stream now occupies this trough, which contains a heavy deposit of silt. The present watershed, in the vicinity of Elmira, is about 400 feet above Bonners Ferry and about 30 feet above Sand Point, on the shore of Lake Pend Oreille. The Purcell trench is not only one of the striking physiographic features of the region, but, as will be later shown, constitutes the dividing line between geological terranes of marked dissimilarity.

The Cœur d'Alene Mountains lie east of the Purcell trench and may be considered as bounded on the northeast by the upper part of Clark Fork, locally known as Missoula River. Having a general northwest trend, they are cut off by the trench obliquely, coming to a point on the southeast shore of Lake Pend Oreille. To the south they merge with the Bitterroot Range and the Clearwater Mountains, near the head of the North Fork of Clearwater River.[a]

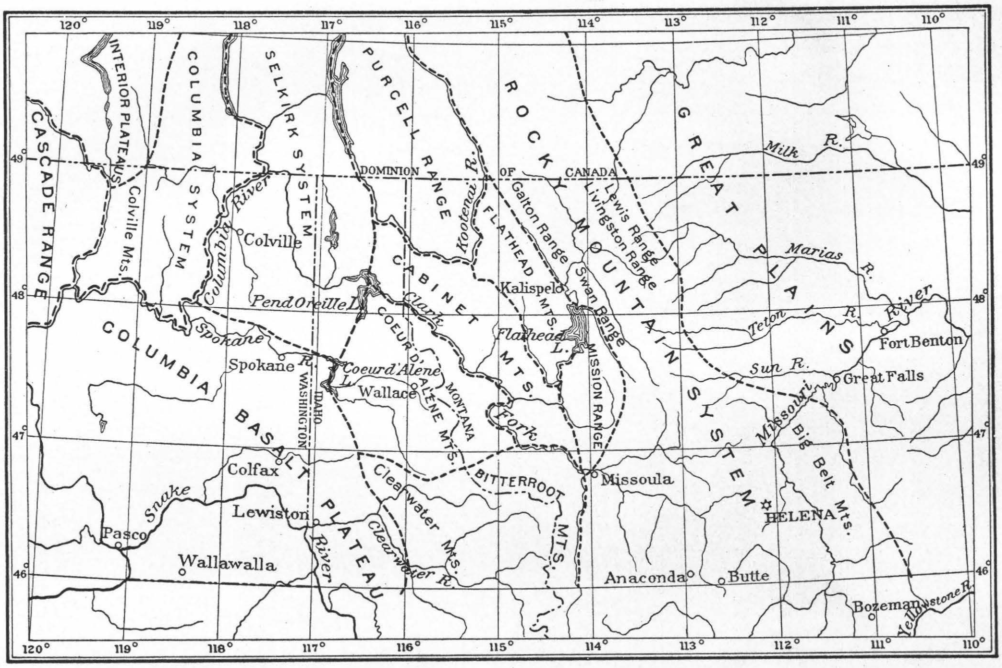


FIG. 2.—Map showing mountain systems in the Cœur d'Alene region. (After R. A. Daly.)

Like the Clearwater Mountains, the Cœur d'Alene Mountains have the general character of a broad, deeply and maturely dissected plateau, sloping gently westward. In the vicinity of the Cœur d'Alene district the width of the western versant is 50 or 60 miles, the altitude ranging from about 7,000 feet along the crest to approximately 2,150 feet on the shore of Cœur d'Alene Lake. The eastern slope is more abrupt, falling, in from 10 to 25 miles, to the valleys of Clark Fork and Missoula River.

Northeast of the Cœur d'Alene Mountains and separated from them by Clark Fork are the much more rugged and picturesque Cabinet Mountains, a simple axial range of northwest-southeast trend, with a length of about 120 miles. The range ends on the northwest at Kootenai River, near Bonners Ferry, and like the Cœur d'Alene Mountains is obliquely cut off by the Purcell trench. On the north the range is bounded by Kootenai River eastward to Jennings, and on the northeast by the rolling, lake-dotted country which extends from the bend of the Kootenai at Jennings to Flathead Lake. The southeastern end of the range is less definite than the northwestern, but may provisionally be placed in the bend of Flathead River at Jocko, Mont.

[a] In Daly's map the Cœur d'Alene Mountains are made to extend too far to the northwest.

According to Mr. Calkins,[a] the northwestern end of the Cabinet Mountains is of the dissected plateau type, although more rugged in detail than the neighboring Cœur d'Alene Mountains. In the middle portion of the range are lofty peaks rising to altitudes estimated by Mr. Calkins at 8,500 to 9,000 feet. He describes the scenery of this part of the Cabinet Mountains as alpine in character, with rock-rimmed tarns and even a few small waning glaciers lying in deep cirques on the north side of the pinnacled crest.

North of the Cabinet Mountains and lying mainly in British Columbia is the Purcell Range as defined by Daly. The southern end of this range is at Jennings, in the bend of Kootenai River; the northern end near Donald, at the junction of Columbia and Duncan rivers. The general trend of this range is north-northwest. It is bounded on the west, from Bonners Ferry northward, by the Purcell trench, and along most of its eastern foot by another linear depression, called by Daly the Rocky Mountain trench, which extends from Flathead Lake to the Kootenai at its eastern crossing of the international boundary and thence coincides with the valleys of the Kootenai and Columbia, extending into British Columbia far beyond the region here under consideration. Between the international boundary and Jennings Kootenai River separates the Purcell Range from the Flathead Mountains, which extend southward between the Rocky Mountain trench and the Cabinet Mountains.

Mr. Calkins, who examined the part of the Purcell Range lying within United States territory, reports that the range is not of particularly rugged topography, although some of the summits attain an altitude of 7,500 feet. At their western edge the mountains overlook the valley of the Kootenai near Porthill in a scarp of noble proportions.

The rugged Mission Range, which overlooks Flathead Lake from the east and stretches southward to the vicinity of Missoula, is the last of the important mountain groups in this general region which it is necessary to enumerate as lying between the Purcell trench and the Columbia River lava plateau on the west and the chain of ranges forming the main Cordilleran crest on the east. To this chain, corresponding to the front ranges in Colorado, Daly has applied the name Rocky Mountain system, a designation less happy than most of those employed in his useful paper, owing to the general and indefinite use of the name Rocky Mountains, which will still cling to ranges farther south that can not be included in the narrow belt which he here calls the Rocky Mountain system. Here belong the Galton, Livingston, and Lewis ranges near the international boundary, the last fronting the Great Plains to the east, and the Swan or Kootenai, Big Belt, and other ranges farther south. It is possible, as Mr. Calkins[b] has suggested, that the Mission Range should also be classed with the members of this system.

## GEOLOGY.

The remarkable topographic feature referred to as the Purcell trench divides the pre-Tertiary rocks of the broad region here considered into two great terranes which are entirely different both in lithological character and in structure.

West of the trench and north of the Columbia basaltic plateau, the rocks composing the eastern slope of the Selkirk Range form a crystalline complex in which gneisses, fine-grained siliceous schists, and metamorphosed limestones are cut by granitic intrusives. The mineralogical composition of these schists, which are mainly fine-grained quartz schists, usually with muscovite, biotite, and sillimanite in various proportions, and their association with beds of schistose quartzite and limestone, show beyond question that the series as a whole originally consisted of sediments—mainly fine-grained sandstones with subordinate beds of limestone. There are some hornblende schists, containing epidote and calcite, which have probably been derived from dioritic or similar igneous rocks, but these are wholly subordinate to the prevailing siliceous varieties. The sediments have been folded, squeezed, and contorted until their broader stratigraphy is no longer legible. In general, the dip of the schistosity, as well as of the bedding where this is discernible, is nearly vertical. It is probable that the metamorphism is directly related to the granitic intrusions, which are batholithic in character and presumably underlie much of the schist at no great depth.

[a] Manuscript of reconnaissance.

[b] Oral communication.

The granitic intrusions are rarely true granites. They usually contain a considerable proportion of plagioclase and are for the most part quartz monzonites or granodiorites, thus suggesting a comparison with the quartz monzonite of the Central Idaho batholith, which is probably post-Triassic. The gneisses are in part at least of similar character and appear to have been derived from the massive intrusives by pressure subsequent to solidification. Wherever the granitic gneisses were found in contact with the siliceous schists the former are clearly intrusive into the latter. It is possible that some of the granitic gneisses exposed along the west shores of Cœur d'Alene and Pend Oreille lakes and along the Great Northern Railway between Spokane and Bonners Ferry may be older than the schists just described, but this seems doubtful.

The age of this assemblage of rocks is unknown. The Shuswap series of Dawson[a] as described by him west of Kootenai Lake, presents some features of resemblance to them, but Daly,[b] who has spent several seasons in a study of the geology along the Canadian side of the boundary, points out that any final correlation between the two sections is as yet premature. Dawson[c] assigns the Shuswap series to the Archean and compares it with the Grenville series of Quebec.

Near the international boundary the group of schists just described continues without notable change in general character from Kootenai River (Purcell trench) westward to the main crest of the Selkirk Range (locally known as the Quartzite Range), or approximately to longitude 117°. Here it is succeeded by a thick series of quartzites with bands of squeezed schistose conglomerate near the base. The quartzites, which in places show the bedding plainly, strike north and south and are nearly vertical, but seem to have a general western dip of about 85°. The width of this zone of quartzitic rocks is probably about 10 miles, but its western limit is not well defined, the beds of quartzite becoming thinner, more schistose, and associated with increasingly numerous bands of dark slaty schists, with occasional lenses of limestone. The quartzites, which are in many places schistose, are cut by masses of granite and granitic gneiss. Daly[d] refers to a great unconformity between these partly schistose quartzites and the finer-grained, more thoroughly schistose rocks on the eastern side of the divide and states that the apparent thickness of the quartzites is increased by overthrust faulting. Although the presence of conglomerates suggests such unconformity, yet these pebbly bands occur at several horizons, intercalated with schists and schistose quartzites, and the writer of the present outline was unable, in the course of the hasty reconnaissance in 1901, to procure decisive evidence of stratigraphic discordance. Farther west the quartzites are succeeded and probably overlain by finely laminated siliceous schists with some quartzite and rather numerous lenses of limestone, all cut by granitic intrusions.

There is no marked lithological change and no evident unconformity in these rocks between the quartzitic zone and slaty schists near Columbia River. The general metamorphism becomes less intense in this direction, although in the vicinity of large granitic areas such as that lying between Metalline, on Clark Fork, and Northport, on Columbia River, thoroughly crystalline schists are abundant.

In the way of summary it may be said that from Kootenai River westward to the Columbia the rocks constitute a much disturbed, highly folded complex in which the metamorphism of the sediments generally diminishes in intensity westward, but which only detailed study can successfully resolve into structural or chronological subdivisions. So far as known, no fossils have been found in this entire stretch of 50 miles along the international boundary, and the age of the rocks has not been determined. Although it appears probable that some of them may be correlated with Dawson's Shuswap, Nisconlith, and Adams Lake or Selkirk series, yet there are indications that considerably younger rocks are involved in the complex. Daly[e]

[a] Ann. Rept. Geol. Survey Canada, new ser., vol. 4, 1890, pp. 30 B-33 B. See also Rept. of Progress, Geol. Survey Canada, 1877-78, 1879, pp. 96 B-101 B.

[b] Summary Rept. Geol. Survey Canada for 1903, 1904, p. 94.

[c] Brit. Assoc. Rept. for 1897, 1898, p. 636.

[d] Summary Rept. Geol. Survey Canada for 1903, 1904, p. 95.

[e] Summary Rept. Geol. Survey Canada for 1902, 1903, p. 143.

considers that there is indirect evidence for the Carboniferous age of the rocks exposed along Pend Oreille River (Clark Fork) and extending westward across the Columbia to Kettle River, thus suggesting a comparison with the Cache Creek group of British Columbia. It is from the north that the problem of determining the age of these metamorphic rocks can be attacked with the best prospect for success. The beds are apparently destitute of fossils south of the international boundary, and the cover of Columbia River basalt on the south leaves little hope of connecting them in that direction with rocks of determinable age.

To the compressed, metamorphosed, and heterogeneous complex just described, the rocks east of the Purcell trench offer a striking contrast. They consist of a thick accumulation of prevailingly arenaceous sediments which show no pronounced regional metamorphism and in which the essential structural features are open folding and extensive faulting. The total thickness of these sediments is estimated by Walcott [a] at 37,000 feet. They are pre-Cambrian in age and constitute the great Belt group of the Algonkian system, which is known to extend from the Belt Mountains across the Rocky Mountain chain to the Purcell trench. Some of the mountain ranges, notably the Purcell, Cabinet, Cœur d'Alene, Livingston, and Lewis, are, with the exception of comparatively small igneous masses, composed entirely of Belt rocks. In others, such as the Mission Range [b] and the Belt Mountains,[c] the Algonkian beds are partly concealed beneath Cambrian and later strata, and in the region adjacent to Butte and Helena [d] these ancient sediments have been invaded by granitic batholiths now exposed over considerable areas. In the Bitterroot and Clearwater mountains, also, the Belt group extending southward from the Cœur d'Alene Mountains is invaded and probably for the most part cut off by the great granitic batholith of central Idaho.[e]

In the Phillipsburg district, Montana, northwest of Butte, Mr. Calkins [f] has found a thick series of conformable beds overlain with striking unconformity by the Cambrian Flathead quartzite. The general succession of these pre-Cambrian beds is similar to that in the Cœur d'Alene district, but differs in the greater total thickness of the reddish beds that form the upper part of the series in both districts and the smaller aggregate thickness of the siliceous beds that constitute the middle portions of both stratigraphic columns.

The Belt sediments are apparently coarsest in the Purcell Mountains and seem to grade toward the east and southeast into shales and limestones, indicating, as Daly [g] points out, that the Algonkian land mass whence the bulk of the sediments were derived lay to the west and northwest of the Purcell Mountains. Walcott [a] finds a trace of an eastern shore line also near Neihart, Mont., where the basal conglomerate of the Belt rests upon Archean rocks. Along the western border of the terrane no base has been found. The Prichard slate, the oldest formation in the Cœur d'Alene Mountains, and the Creston quartzite, the oldest formation in the Purcell Range and probably the stratigraphic equivalent of the Prichard,[h] are cut off along the Purcell trench without any exposure of true basal beds.

The most striking tectonic feature of the western part of the Algonkian terrane is the existence of great faults of general northwest trend. The courses of Kootenai River and Clark Fork where they serve as boundaries between the Purcell, Cabinet, and Cœur d'Alene mountains are at least partly determined by faults of this group,[h] and another, the Osburn fault, is one of the most pronounced features of the geological structure of the Cœur d'Alene district.

It is not the purpose of this outline to discuss the correlation of the various Algonkian sections studied by the writers of this report in the Cœur d'Alene district, by Daly in the Purcell Range, by Willis in the Lewis and Livingston ranges, by Walcott in the Mission and other

[a] Algonkian formations of northwestern Montana: Bull. Geol. Soc. America, vol. 17, 1906, p. 27.

[b] Walcott, C. D., Algonkian formations of northwestern Montana: Bull. Geol. Soc. America, vol. 17, 1906, p. 3.

[c] Little Belt Mountains folio (No. 56), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

[d] Butte Special folio (No. 38), Geologic Atlas U. S., U. S. Geol. Survey, 1897. Barrell, Joseph, Geology of the Marysville mining district, Montana: Prof. Paper U. S. Geol. Survey No. 57, 1907, p. 54.

[e] Lindgren, W., A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, p. 16.

[f] Oral communication.

[g] Summary Rept. Geol. Survey Canada for 1904, 1905, p. 96.

[h] Calkins, F. C., reconnaissance manuscript.

ranges farther east, and by Weed in the Little Belt Mountains. The reader who wishes to pursue the subject further is referred to the recent paper by Walcott [a] and to the forthcoming reconnaissance bulletin by Mr. Calkins. Some further treatment of the same subject will be found also in the portion of this report dealing with the general geology of the Cœur d'Alene district, by Mr. Calkins.

The absence of any visible stratigraphic base to the Belt rocks along the Purcell trench suggests that this feature corresponds to a zone of faulting whereby the Algonkian sediments on the east have been dropped against the crystalline rocks on the west. Daly,[b] working north of the international boundary, notes that the Algonkian has been faulted down against the "much older crystalline mass" to the west of the Kootenai Valley. He concludes that the valley has probably been eroded along a zone of faulting.

That the trench corresponds to a fault zone is probably true, but it is by no means certain that the rocks immediately west of the zone are Archean or that they are a part of the ancient floor upon which the Belt sediments were laid down. Mr. Calkins [c] observed in 1905 that the Creston quartzite north of Bonners Ferry is intruded by a porphyritic quartz monzonite. This granitic intrusive extends northward to Porthill and is probably the same as that mentioned by Daly as forming Rykert Mountain. This rock passes into gneissic modifications, and it is quite possible that the augen gneiss which occurs west of Kootenai River near the boundary and which constitutes part of the crystalline complex may be really post-Algonkian. In other words, the crystalline schists west of the Purcell trench may be Algonkian or even younger sediments which owe their intense metamorphism to the intrusion of post-Algonkian granitic rocks accompanied by intense deformation. It is thus evident that the geological interest of the Purcell trench, quite apart from problems connected with its Tertiary and Quaternary history, is by no means exhausted. The relations of the sharply contrasting rocks on either side still invite detailed investigation.

The region adjacent to the Cœur d'Alene district contains no direct record of post-Algonkian sedimentation. If Paleozoic or Mesozoic rocks were deposited, they appear to have been entirely removed prior to Miocene time. At the beginning of the Miocene the Belt sediments had probably long been folded and faulted into essentially their present structure and erosion had sculptured them into a topography not greatly different from that of to-day, as shown by the fact that the Miocene lava flood sent tongues of basalt up existing valleys. Thus Cœur d'Alene Lake occupies a river valley which was filled in part with basalt in Miocene time, was afterward recut by the original river, leaving terraces of basalt on the old slopes, and was finally dammed on the north by a deposit of Pleistocene gravels which may have been transported southward along the Purcell trench from the retreating ice front, resulting in the formation of the lake and the backing up of the water in Cœur d'Alene and St. Joseph rivers.

It is not possible to fix accurately the age of the principal deformation of the Belt rocks in the Cœur d'Alene region. Lindgren [d] has shown that the quartz monzonite batholith of the Bitterroot and Clearwater mountains is probably post-Jurassic. That intrusion was undoubtedly associated with orogenic uplift and with deformation of the sedimentary rocks. It is likely that most of the folding and faulting of the Cœur d'Alene beds occurred at this time, although it is possible that several earlier epochs of deformation may have affected the region during the long interval between the close of the Algonkian and the post-Triassic granitic intrusion. After the intrusion the whole of central and northern Idaho was uplifted as a plateau and this plateau was deeply dissected prior to the eruption of the Columbia River lava.

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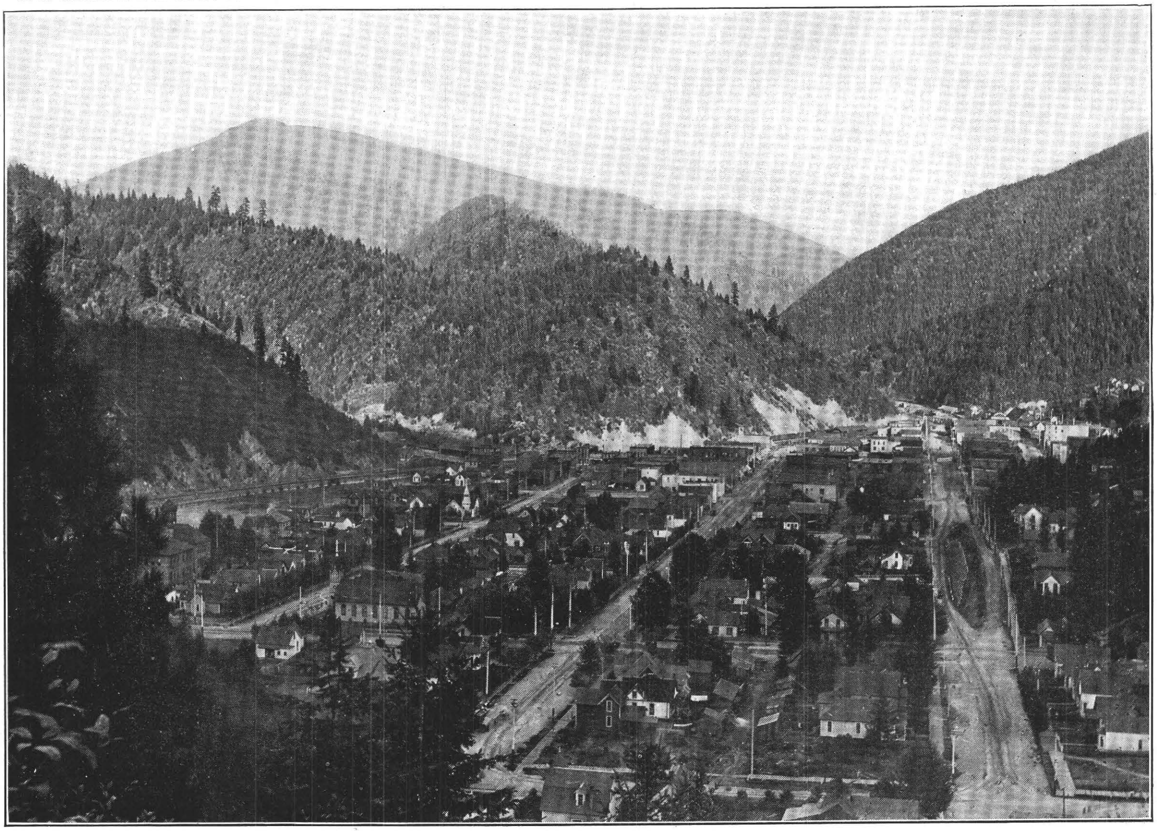
[a] Algonkian formations of northwestern Montana: Bull. Geol. Soc. America, vol. 17, 1906, pp. 1-28.

[b] Summary Rept. Geol. Survey Canada for 1903, 1904, p. 97.

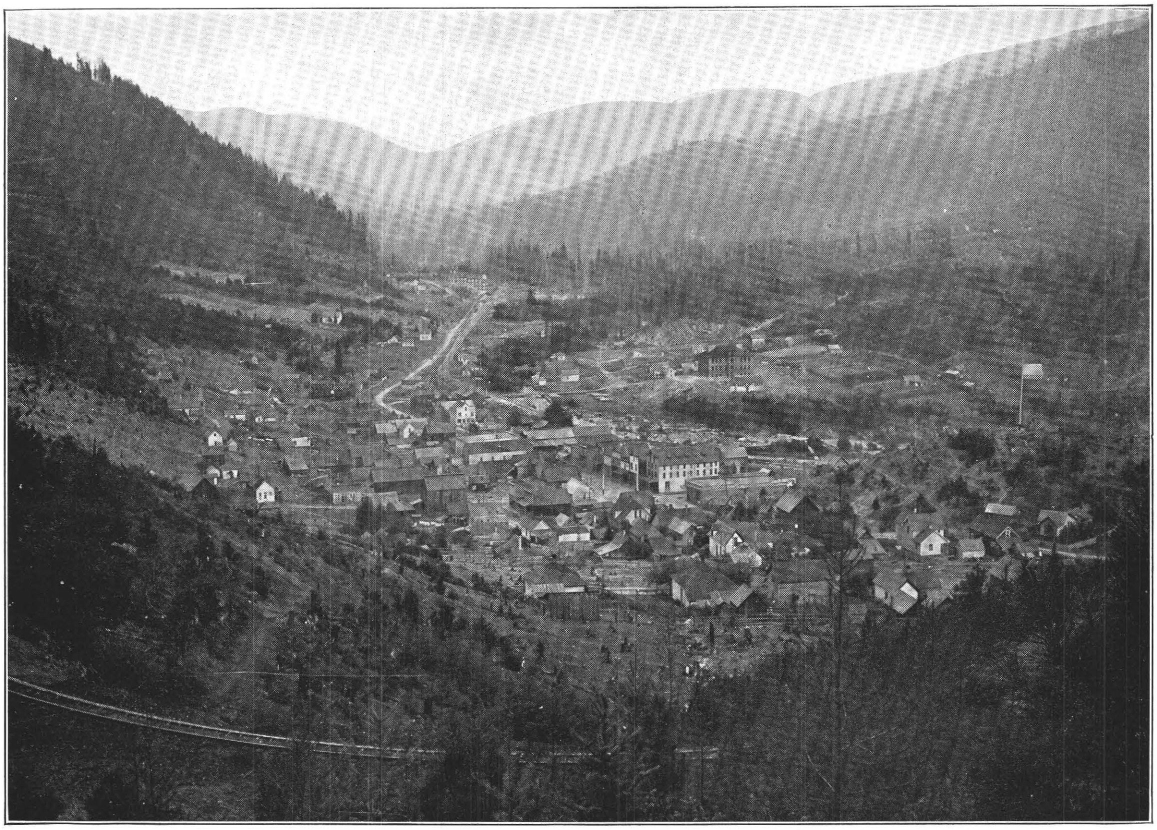
[c] Reconnaissance manuscript.

[d] Op. cit., p. 20.



*A.* TOWN OF WALLACE, FROM THE WEST.

The mouth of Ninemile Creek appears on the left. Beyond may be seen the valleys of Canyon Creek on the left and of the South Fork of Cœur d'Alene River on the right.



*B.* TOWN OF MULLAN, FROM THE WEST.

The narrow-gage railway of the Morning mine appears in the foreground. In the distance, beside the old Mullan road, is the mill of the Gold Hunter mine. To the right of the river are gravel terraces.

## INDUSTRIES AND SETTLEMENTS WITHIN THE CŒUR D'ALENE DISTRICT.

Were it not for the mines, the Cœur d'Alene district would be nearly as complete a wilderness as when Lieutenant Mullan constructed the first road across the Cœur d'Alene Mountains, forty-five years ago. There is almost no arable land, and the timber, while good enough for mining purposes, would probably not have been sufficient inducement to bring railroads into the region. Mining is the one paramount industry of the district, and upon it all others depend. The gross value of the metallic product in 1906 was, in round figures, $16,000,000. Approximately 4,000 men are employed in the mines and concentrating works, and the total population of the district is estimated at 8,000 to 10,000.

Wallace (Pl. III, *A*), the principal town and the seat of Shoshone County, contains about 3,500 people and is situated at the confluence of Canyon and Ninemile creeks with the South Fork of Cœur d'Alene River. This situation and the fact that it is the terminus of the Oregon Railroad and Navigation Company's line from the west and the Cœur d'Alene branch of the Northern Pacific Railway from the east make it the chief distributing point of supplies for the district. Branch railway lines run from Wallace up Ninemile Creek and up Canyon Creek to the town of Burke (Pl. XXIV, *B*, p. 168). Mace, Black Bear, and Gem are mining hamlets between Wallace and Burke. The town next to Wallace in importance is Wardner (Pl. IV, *A*, p. 22), near the western border of the district. This town, with the adjoining settlement of Kellogg on the north, depends for its existence on the Bunker Hill and Sullivan and Last Chance mines. As the workings in these mines increase in depth and the upper levels become abandoned, Kellogg, with its advantage in position, is likely to become the more important place.

Mullan (Pl. III, *B*), 6 miles due east of Wallace, is the local supply point for the Morning, Gold Hunter, and Snowstorm mines. Murray, on the north side of the district, is now a town of small commercial importance; but it is well situated, and as there is some likelihood, in view of the increasing prominence of the lead-silver deposits near the head of Prichard Creek, of a railway being built up the North Fork of the Cœur d'Alene, this old center of the gold-mining industry may experience a revival of prosperity.

## LITERATURE.

The following list is not intended to include scattered articles in mining journals, which as a rule are of transient interest, but only those more important publications which a reader interested chiefly in the geology of the district might care to consult.

### GEOGRAPHY AND HISTORY.

MULLAN, Capt. JOHN, U. S. Army. Report on the construction of a military road from Fort Walla Walla to Fort Benton. Washington, D. C.

Relates to early history of Cœur d'Alene district.

MULLAN, Capt. JOHN. Miners' and travelers' guide to Oregon, Washington, Idaho, Montana, Wyoming, and Colorado, via the Missouri and Columbia rivers. New York, 1865.

General description of the Cœur d'Alene region before the gold or lead-silver deposits were discovered.

"Cœur d'Alene Sun." Newspaper published at Murray by Adam Aulbach.

Began as the "Belknap Sun" May 13, 1884, and constitutes an unusually full and reliable record of the early development of the district.

DALY, REGINALD A. The nomenclature of the North American Cordillera between the 47th and 53d parallels of latitude. Geog. Jour., vol. 27, 1906, pp. 586-606.

Discusses the grouping and nomenclature of the mountain ranges to the west, north, and east of the Cœur d'Alene district.

### GENERAL GEOLOGY OF THE REGION, PARTICULARLY AS REGARDS THE BELT GROUP OF PRE-CAMBRIAN SEDIMENTS.

WEED, W. H., and PIRSSON, L. V. Geology of the Castle Mountain mining district, Montana. Bull. U. S. Geol. Survey No. 139, 1896, pp. 32-34.

Describe the Belt terrane, now known as the Belt group, as exposed between the Big Belt and Little Belt Mountains.

WALCOTT, C. D. Pre-Cambrian fossiliferous formations. Bull. Geol. Soc. America, vol. 10, 1899, pp. 199–244.
Summarizes the earlier literature on the sedimentary rocks of the Belt Mountains. Establishes existence of a great unconformity between the Belt rocks and the Cambrian beds and announces discovery of fossils in the pre-Cambrian.

WEED, W. H. Little Belt Mountains folio (No. 56), Geologic Atlas U. S., 1899.
Describes the Belt group in the type locality.

WEED, W. H. Geology of the Little Belt Mountains, Montana. Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 256–581.
Describes the Belt group.

WILLIS, BAILEY. Stratigraphy and structure, Lewis and Livingston ranges, Montana. Bull. Geol. Soc. America, vol. 13, 1902, pp. 305–352.
Describes pre-Cambrian rocks which are probably the northeast extension of the Cœur d'Alene sediments.

DALY, REGINALD A. Summary reports of the Geological Survey of Canada for the calendar years 1902 (pp. 136–147, 1903), 1903 (pp. 91–100, 1904), and 1904 (pp. 91–100, 1905).
Notes on the general geology of the international boundary region, particularly on the pre-Cambrian sediments.

WALCOTT, C. D. Algonkian formations of northwestern Montana. Bull. Geol. Soc. America, vol. 17, 1906, pp. 1–28.
Discusses character, thickness, and distribution of the Belt group.

## THE ORE DEPOSITS.

FINLAY, J. R. The mining industry of the Cœur d'Alenes, Idaho. Trans. Am. Inst. Min. Eng., vol. 33, 1903, pp. 235–271.
An excellent summary of the statistics and technology of the lead-silver mines, with important notes on the geology and structure of the deposits.

LINDGREN, W. A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho. Prof. Paper U. S. Geol. Survey No. 27, 1904. Especially pp. 108–111.
Describes briefly the geology and ore deposits of the Cœur d'Alene district. Recognizes the metasomatic character of the ores. Describes also the general geology of the region lying south of the district, especially the great monzonitic batholith of central Idaho and the relation of this intrusive mass to sediments on Lolo Creek, Montana, which are probably representative of a part of the sedimentary series of the Cœur d'Alene district.

RANSOME, F. L. Ore deposits of the Cœur d'Alene district, Idaho. Contributions to economic geology, 1904: Bull. U. S. Geol. Survey No. 260, 1905, pp. 274–303.
A preliminary statement of some of the results embodied in the present report.

BELL, ROBERT N. Reports of the State inspector of mines for the years 1904, 1905, and 1906. Boise, Idaho.
Contains notes on mining development and production.

COLLIER, ARTHUR J. Ore deposits in the St. Joe River basin, Idaho. Contributions to economic geology, 1905: Bull. U. S. Geol. Survey No. 285, 1906, pp. 129–139.
Sketches the undeveloped mineral resources of the region south of the Cœur d'Alene district.

MACDONALD, D. F. Economic features of northern Idaho and northwestern Montana. Contributions to economic geology, 1905: Bull. U. S. Geol. Survey No. 285, 1906, pp. 41–52.
Embodies some results of reconnaissance work north of the Cœur d'Alene district.

# PART I.—GENERAL GEOLOGY.

By Frank Cathcart Calkins.

## CHAPTER I.—TOPOGRAPHY.

### GENERAL CHARACTER.

The Cœur d'Alene district is one of strongly marked relief. It contains no extensive flat areas, either on valley bottoms or plateaus, and its surface is composed in greater part of steep slopes produced by the erosion of multitudinous branching streams. The profiles of the principal streams and of the main ridge crests display, however, a rather close approach to horizontality. If the streams have not excavated very broad valleys, they have, on the other hand, rather gentle grades in proportion to their length, and their lower courses have alluvial borders of considerable width. The uniformity of level shown by the principal crest lines, as illustrated in Pl. IV, is a rather striking feature of the topography. A large proportion of the upland surface lies at elevations of 5,500 to 6,500 feet, and its general aspect in views from commanding stations suggests a dissected plateau. In short, the character of the topography of the region is such as might result from the thorough dissection by streams of a former surface of low relief.

Owing to the prevalence of even sky lines and to the lack of such diversity as is given to some other regions by the contrast of broad areas of level ground with adjacent masses of hills, the scenery of the Cœur d'Alene Mountains, in spite of its strong relief, tends to be monotonous. It is redeemed, however, by certain details of sculpture due to the powerful agency of its vanished glaciers. On the northerly sides of the more lofty peaks and ridges lie steep-walled cirques, many of which contain blue rock-rimmed lakelets, and others luxuriant flowery meadows.

### DRAINAGE.

The dominant watercourses of the district are the North and South forks of Cœur d'Alene River, which unite a few miles beyond the western boundary of the district. Of these the North Fork is by far the larger. Although broken here and there by rapids, its current is for the most part gentle, its fall within the district being about 10 feet to the mile, and it is navigable for small boats. The South Fork, which has its source but little beyond the eastern boundary of the district, is hardly to be ranked as a river. Its average gradient in its course through the district is about 80 feet to the mile, and its waters, opaque with gray mud from the concentrating mills, are turbulent and shallow.

The only important streams that head in the district on the Montana side of the Cœur d'Alene crest are St. Regis River and Prospect Creek, the first of which joins the Missoula, while the second flows directly into the Clark Fork of Columbia River.

The principal tributaries that enter the North Fork of Cœur d'Alene River within the district are Prichard and Beaver creeks, both of which, considering their size, have low gradients and broad valleys. The largest affluent of the South Fork, almost equal in flow to the main stream above the junction, is Canyon Creek, so called from the steep-walled ravine which it has made for itself in the hard rocks through which it flows. Ninemile Creek, which empties only half a mile farther west, is a shorter stream, which has, however, a grade practicable for a railroad for several miles from its mouth. Several other short streams with bottoms broad enough to afford some land available for agriculture flow into the South Fork from the north side. The tributaries that enter it from the south are mostly short and occupy narrow, steep-sided gulches; but there are two, Big Creek and Placer Creek, which drain extensive basins.

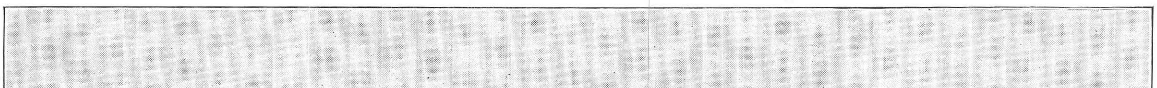
## PRINCIPAL FEATURES OF RELIEF.

The highest ridges in the district are in general the divides between the largest streams, and their height diminishes in proportion as the intervening valleys broaden. A gently rolling surface tangent to the highest summits would accordingly have a very gradual slope to the northwest, away from the two principal divides that cross the area and toward the junction of the two streams into which most of it drains. These divides, rather sinuous and uneven in height, and rising little above the general level of the hills on either side, are, first, the main crest of the Cœur d'Alene Mountains, already mentioned; and, second, the ridge that forms the southern limit of the basin of Cœur d'Alene River, and parts its waters from those of the St. Joseph. The former, although without any very conspicuous summits, has the greatest average elevation of any ridge in the district; the latter, somewhat inferior to it in average height, bears Stevens Peak, the dominant summit of the northern part of the Cœur d'Alene Mountains. This peak lies near the junction of the two principal ridges and not far from the southeast corner of the area mapped. The lowest point, that at which the main fork of Cœur d'Alene River leaves the district, is near the opposite or northwest corner. The elevations of these two points are respectively 6,826 feet and 2,240 feet, and the difference, 4,386 feet, gives a measure of the comparatively high relief of the region.

Two prominent spurs form the divides on either side of Canyon Creek. The more northern one has several of the highest summits of the region, the most important being Granite, Tiger, and Custer peaks. The western part of the district has a less accentuated topography than the eastern part, and contains few prominent summits. The hills between the forks of Cœur d'Alene River are rounded, brushy, and monotonous in aspect. Kellogg Peak, however, 6,296 feet above the sea, and a summit of almost the same elevation a mile farther west, rise boldly at the head of the stream that drains through Wardner, and are the more conspicuous because they so markedly dominate their surroundings.

*A.* VIEW LOOKING NORTH OVER THE CŒUR D'ALENE MOUNTAINS FROM THE STEMWINDER TUNNEL ABOVE WARDNER.

Shows mature dissection of plateau-like uplift. Town of Wardner in foreground; Kellogg in the middle ground, partly concealed by the conical hill known as Haystack Peak.



*B.* VIEW LOOKING EAST FROM HAYSTACK PEAK UP THE SOUTH FORK OF CŒUR D'ALENE RIVER TOWARD THE CREST OF THE RANGE.

Shows the gradual slope and evenness of ridge lines characteristic of the western versant of the Cœur d'Alene Mountains, and terraces south of the river in the middle distance.

# CHAPTER II.—STRATIGRAPHY.

## GENERAL CLASSIFICATION OF ROCKS.

The rocks of the Cœur d'Alene district may be divided for purposes of description into three main groups. The first comprises the pre-Cambrian sediments of the Belt group, whose broad features and distribution have been indicated in the general introduction. These are the only consolidated sedimentary rocks of the district, which affords no exposures of an underlying Archean complex or of the later Paleozoic strata that are found to the east. In the second group are the igneous rocks intruded into the pre-Cambrian sediments. In the third are the unconsolidated deposits of sand, gravel, and silt, Tertiary and Quaternary in age, which lie in patches upon the eroded surfaces of the ancient rocks and form the floors of the valleys.

## PRE-CAMBRIAN SEDIMENTS.

### SUCCESSION AND GENERAL CHARACTER OF FORMATIONS.

#### INTRODUCTORY STATEMENT.

The subdivision of the pre-Cambrian series in the Cœur d'Alene district must be based, in the absence of fossils, on lithologic grounds alone. It is fortunate, therefore, that the district, although on the whole rather poor in exposures, contains a number of well-exposed sections and that the stratigraphic column falls into natural divisions each characterized by lithologic features of diagnostic value. This makes it possible to work out the general sequence of beds. For purposes of mapping and description the series has been divided into six formations. Although these formations, regarded as wholes, are well-individualized units, the precise horizons of the division planes that separate them are matters for somewhat arbitrary decision. Without exception, contiguous formations grade one into another and they all succeed one another conformably. In the descriptions which follow, the criteria by which the planes of separation are fixed will be set forth as clearly as possible, and emphasis will be placed on the distinctive characters of each stratigraphic unit.

The following brief characterization of the formations, in order of age, is intended to give the reader a general conception of the character of the pre-Cambrian sediments in the Cœur d'Alene district, and to lay a foundation for an attempt at broad correlation with the formations of other regions.

#### PRICHARD SLATE.

The Prichard formation is named from Prichard Creek, which drains a large part of the most extensive area occupied by this formation within the Cœur d'Alene district. It is a very thick accumulation of sediments, composed in greater part of argillite (indurated mud), regularly banded in lighter and darker shades of blue gray. The weathered surface is commonly stained with reddish-brown oxide of iron. The formation comprises also some gray indurated sandstone, which occurs at various horizons, but is especially abundant near the top. The upper strata, besides being more siliceous than the lower, are characterized by abundant evidences of deposition in shallow waters. Their character is intermediate between that of the main body of the Prichard and that of the overlying Burke, but they contain a considerable amount of the characteristic bluish argillite.

The general aspect of the formation as seen in distant views is determined by the dark color prevailingly shown by both fresh and weathered surfaces, and by a general scarcity of prominent outcrops, except where some of the thicker beds of sandstone reach the surface. The formation is more easily eroded than those which overlie it and does not form any of the higher peaks in the district.

### BURKE FORMATION.

The Burke formation is so named because of its extensive areal development and good exposure in the vicinity of the town of Burke. It is composed of siliceous rocks, prevailingly fine grained, thin bedded, and of a light greenish-gray tint. Their lithologic character ranges, however, from that of fairly pure, nearly white quartzite to that of dark-gray siliceous shale. The quartzite is more abundant in the upper and the shale in the lower part of the formation, which therefore exhibits a transition into the quartzitic and argillaceous formations that lie above and below it, respectively. The Burke formation is characterzied from top to bottom by shallow-water features.

In comparison with the Prichard, the Burke is distinguished by lighter color and stronger resistance to erosion. Extensive exposures of it, little obscured by vegetation, are common, and it forms many of the more lofty summits of the district, as, for example, Custer and Tiger peaks.

### REVETT QUARTZITE.

The Revett formation is named from Revett Lake, east of Granite Peak. Although the lake basin does not itself lie in this formation, the steep slopes that border the basin on three sides are carved from its rocks.

The formation is composed mainly of hard white thick-bedded quartzite, although it comprises some softer arenaceous beds. In general the middle part of the formation is the most purely siliceous, and the lowermost and uppermost parts are softer and thinner bedded, thus approaching the contiguous formations in lithologic character.

The Revett quartzite is, of all the formations in the district, the one which most strongly resists erosion and which is with greatest difficulty decomposed into soil. It, therefore, constitutes the summits of many elevated peaks and ridges, of which Kellogg Peak, Granite Peak and the ridge south of it, and Snowstorm Peak are among the more conspicuous examples. It breaks down into angular blocks that form extensive talus slopes, the one on the west side of the Granite Peak ridge in particular constituting a white expanse that catches the eye even at a distance of many miles. (See Pl. XXIV, *B*; hill in background.)

### ST. REGIS FORMATION.

The stratigraphic unit next above the Revett quartzite has been named the St. Regis formation because of its extensive development about the headwaters of St. Regis River. This formation resembles the Burke in the general composition and texture of its rocks, which are indurated shales and sandstones abundantly marked with sun cracks, ripple marks, and other evidences of deposition in shallow water. In contrast to the light-colored Burke rocks, however, the St. Regis beds are dark green or purple, the latter color being especially characteristic.

In resistance to erosion, this formation is about equal or perhaps a little inferior to the Burke. It forms no very conspicuous summits, but is exposed in a number of precipitous cliff sections, as, for example, on the North Fork of Cœur d'Alene River and west of Twentytwo Mile Creek.

### WALLACE FORMATION.

The Wallace formation is named from the principal town of the district, which is surrounded by hills carved from the formation, and whose vicinity affords several good though not very extensive exposures of portions of it. The Wallace consists chiefly of thin-bedded rocks which contain in considerable amount the carbonates of calcium, magnesium, and iron. This feature of its composition is highly characteristic, and distinguishes it from all other formations in the district. The formation exhibits a greater range of lithologic variation than any of the others, the general types comprised in it being argillites, limestones, more or less magnesian, and indurated sandstones, with intermediate varieties composed of varying amounts of mud, sand, and carbonate. The lower part is composed chiefly of green slate containing more or less carbonate; the middle part of thin alternating layers of impure limestone, bluish and greenish-gray argillites, and a light-colored indurated calcareous sandstone or quartzite; and the upper part chiefly of more or less calcareous argillite with some thin laminæ of limestone.

The Wallace formation is composed on the whole of more easily weathered rocks than any of the other Cœur d'Alene formations, and their decomposition gives rise to a fertile soil. Its bold outcrops therefore have relatively small area in comparison with its total surficial development, and it supports a heavy growth of vegetation. It is exhibited, however, in some good exposures, of which those near Stevens Peak are the most extensive.

### STRIPED PEAK FORMATION.

The Striped Peak formation is named from a mountain situated between the heads of Big Creek and Placer Creek, on whose crest its varicolored beds, dipping at a moderate angle, are well exposed and give the peak the appearance which suggested its name. The formation, whose top has been removed by erosion, is so similar to the St. Regis that further description of its lithologic character is unnecessary at this point.

### RÉSUMÉ.

The succession, general lithologic character, and approximate thickness of the Algonkian formations are summarized in the following table, in which the formations are numbered in order of age.

*Generalized tabular section of Algonkian rocks in the Cœur d' Alene district.*

| No. | Name. | Description. | Approximate thickness in feet. |
|---|---|---|---|
| 6 | Striped Peak formation | Sandstones, siliceous, generally flaggy to shaly; colors mostly green and purple; characterized by shallow-water features, as ripple marks, sun cracks, etc. Top removed by erosion. | 1,000+ |
| 5 | Wallace formation | Thin bedded, bluish and greenish, more or less calcareous shales, underlain by rapidly alternating thin beds of argillite, calcareous sandstone, impure limestone; these underlain in turn by gray-green siliceous argillites. Ripple marks, sun cracks, etc., throughout. | 4,000 |
| 4 | St. Regis formation | Indurated shales and more or less flaggy sandstones; colors mostly green and purple; characterized by shallow-water features. | 1,000 |
| 3 | Revett quartzite | White quartzites, generally rather thick bedded; interstratified with subordinate quantities of micaceous sandstone. | 1,200 |
| 2 | Burke formation | Light-gray, flaggy, fine-grained sandstones and shales, mostly greenish, with a variable amount of purple quartzitic sandstone and white quartzite. Shallow-water features throughout. | 2,000 |
| 1 | Prichard slate | Mostly argillite, blue-black to blue-gray, generally showing distinct and regular banding. Considerable interbedded gray indurated sandstone. Upper portion characterized by numerous alternations of argillaceous and arenaceous layers, and by shallow-water features. Base not exposed. | 8,000+ |
| | | | 17,200 |

## REGIONAL CORRELATION.

Nearly all the investigators of the Belt group whose work has been mentioned in the general introduction have applied local names to the subdivisions of the series which they have recognized in their respective fields of study. Most of them, indeed, have been constrained to such a procedure by the lack of data for correlation with type sections. The authors of the present report, however, have retained local names for the pre-Cambrian formations of the Cœur d'Alene district, in spite of the fact that this difficulty has been in great measure removed by Walcott's recent comparative review of the whole field of Belt stratigraphy,[a] and his general correlation, presented in tabular form, of the various sections examined by himself and others. There still remain several obstacles to the application of a uniform scheme of nomenclature to the whole region and to the application of the oldest formation names in any given district. Although rough equivalency between certain large groups of strata may now be asserted, the

[a] Algonkian formations of northwestern Montana: Bull. Geol. Soc. America, vol. 17, 1906, p. 18.

equivalency between minor subdivisions can not be established until by detailed work the changes of each formation have been traced from point to point. Moreover, large masses of strata, in one region too homogeneous for subdivision, become gradually differentiated, so that in another region they comprise two or more lithologically distinct members. Both the large and the smaller units are "formations" in the ordinarily accepted sense, but the restrictions imposed on the employment of such terms as "formation," "group," and "series" by Survey usage obviously make adjustment difficult in such a case. Evidently, therefore, the harmonizing of the nomenclature of the Belt group, though desirable, is an object whose attainment must be deferred without impatience for some years to come.

The attainment of this object and general study of the pre-Cambrian of Montana and Idaho may be furthered a little, however, by indicating how far the stratigraphic subdivisions recognized by various authors may be correlated. The discussion of this subject which follows presents little that is original, for it is based chiefly on the work of Walcott, just referred to. It takes account, however, of some data that were not available to him and omits the discussion of some minor sections. The principal facts are presented in the accompanying correlation table, whose arrangement follows Walcott in its main features. In this table the heavy lines indicate the divisions that can be identified in more than one section.

The calcareous formation variously designated by the terms Newland, Altyn, Blackfoot, and Wallace has been chosen by Walcott as the principal horizon for correlation, and this choice is justified in several ways. Lithologically, this formation is distinguished by being one of only two distinctly calcareous formations in a series composed predominantly of indurated sandstones and shales. Throughout the region, although varying in detail, it is composed chiefly of thin-bedded rocks rich in carbonates, which are in part ferruginous, as is shown by the buff tints so generally characterizing weathered surfaces. Its limestones are generally described as largely siliceous, and are very different from the purer, more distinctly crystalline and thicker-bedded limestones which characterize the Paleozoic formations of this region. Its thickness is relatively more constant than that of any other formation in the series, and it is the only formation recognizable in all the principal sections. But perhaps its most important qualification as a horizon marker consists in the fact that in many localities crustacean remains, worn trails, etc., constituting a sparse but characteristic fauna, have been found near its upper limit.

Immediately beneath this calcareous formation there is found in most sections an assemblage of light-colored siliceous beds, named Ravalli "series," Kitchener quartzite, etc. These seem to attain their maximum development in the Swan Range, but are nearly as thick in the Cabinet and Purcell ranges. In the Cœur d'Alene district their thickness is considerably less than to the north and east, but still very great. Southeastward from the Swan Range toward the Belt region their thickness markedly decreases. The Phillipsburg section contains only about 2,000 feet of beds apparently representing this division, and in the Belt region no corresponding formation has been recognized. The upper part of the Chamberlain shale, however, is described as gray,[a] and is probably as nearly allied lithologically to the Burke formation of the Cœur d'Alene section as to the Prichard, which the lower dark-colored part of the Chamberlain formation resembles; it may therefore be representative of the coarser siliceous beds in question, exemplifying the general increase in the fineness of the sediments which may be observed in traversing the region from northwest to southeast.

The lithologic homogeneity of this siliceous group varies considerably from place to place. In the Cœur d'Alene district it is readily divisible into three formations. In the Cabinet Range the central part is locally similar to the Revett quartzite of the Cœur d'Alene section, but elsewhere it is not distinct from the upper and lower parts of the group, which then can not be subdivided. The purple and green tints which appear faintly in some of the lower beds are more pronounced in the upper. In the Purcell Range the group as a whole has been named by Daly the Kitchener quartzite, and appears to be incapable of subdivision. The Swan Range section of the Ravalli "series" described by Walcott is apparently very similar to that observed

[a] Walcott, C. D., Pre-Cambrian fossiliferous formations: Bull. Geol. Soc. America, vol. 10, 1899, p. 209.

*Correlation of principal sections of Algonkian sediments in Montana and Idaho.*

| Belt Mountains (Walcott). | Lewis and Livingston ranges (Willis). | Phillipsburg district (Calkins). | Mission Range (Walcott). | Cœur d'Alene district (Calkins). | Cabinet Range, western and central parts (Calkins). | Forty-ninth parallel, between crossings of Kootenai River (Daly). |
|---|---|---|---|---|---|---|
| Cambrian.<br>——Unconformity.——<br>*Marsh.* Shale, red, 800 feet. | Top not seen.<br>*Kintla.* Shale, maroon red; ripple marks, etc.; some quartzitic and calcareous beds. 800 feet.<br>*Sheppard.* Quartzite, yellow, ferruginous. 700 feet. | | Cambrian.<br>——Unconformity.——<br>*Camp Creek.* Sandstones, gray, rather thin bedded. 1,762 feet. | | | |
| *Helena.* Limestone, with some shale. 2,400 feet. | *Siyeh.* Limestone, dark blue or gray, weathering buff, with shale interbedded. 4,000 feet. | | Shales, sandstones, and limestones. 1,560 feet. | | Shales and sandstones, medium to thin bedded; color prevailingly greenish gray, but in part red and purple. Shales partly calcareous and weathering buff. A little white crystalline limestone, weathering yellow, at several horizons. Base not seen. 10,000 ± feet. | |
| *Empire.* Shales, greenish gray. 600 feet.<br>*Spokane.* Shales, with thin beds of sandstone; deep red. 1,500 feet.<br>*Greyson.* Shales, mostly dark gray. 3,000 feet. | *Grinnell.* Shale, partly arenaceous; dark red; ripple-marked and sun cracked. 1,800 feet.<br>*Appekunny.* Shale, gray, black, and greenish, interbedded with white quartzite. 2,000 ± feet. | Cambrian.<br>——Unconformity.——<br>*Camp Creek.* Shale and sandstone, the latter prevailing in upper portion. Color chiefly red. 5,000 + feet. | Sandstones, mostly reddish. 4,491 feet.<br>Sandstones, largely shaly, colors red and gray, with 198 feet of limestone 700 feet below top. 3,887 feet. | *Striped Peak.* Shales and sandstone, red and green. 1,000 + feet. | *Striped Peak.* Shales and shaly sandstones, prevailingly dark red; ripple marks, etc. 2,000 + feet. | *Yahk.* Quartzite. 500 feet. |
| *Newland.* Limestone, impure, weathering buff, with interbedded shale. 2,200 feet. | *Altyn.* Limestone, upper part thin bedded and ferruginous; lower part grayish blue, massive, siliceous. 1,400 feet.<br>Base not exposed. | *Newland.* Limestone, thin bedded, more or less siliceous and ferruginous, passing into shale; generally buff on weathered surface. 4,000 feet. | *Blackfoot.* Limestone, thin bedded, more or less siliceous; siliceous layers, weathering buff, interbedded with calcareo-arenaceous shales. 4,805 feet. | *Wallace.* Shales, more or less calcareous, interbedded with thin layers of siliceous and ferruginous limestones and calcareous sandstone. Limestones and calcareous shales weather buff. 4,000 feet. | *Wallace.* Limestones, thin bedded, siliceous and ferruginous, interbedded with more or less calcareous shales. 5,000 ± feet. | *Moyie.* Argillite. 3,400 feet. |
| *Chamberlain.* Shale, mostly black, with some sandstone. 1,500 feet. | | *Ravalli.* Quartzite, gray, with some dark bluish and greenish shale. 2,000 feet. | *Ravalli.* Sandstones, quartzitic, fine grained, purplish gray and gray. 2,550 feet.<br>Sandstones, compact, gray. 1,060 feet.<br>Sandstones, greenish gray, fine grained, in layers 4 inches to 2 feet thick. 4,645 feet. Base not seen. Total Ravalli, 8,255 feet. | *St. Regis.* Shales and sandstones, purple and green. 1,000 feet.<br>*Revett.* White quartzite, partly sericitic. 1,200 feet.<br>*Burke.* Indurated siliceous shales, with sandstones and quartzites, prevailingly gray-green. 2,000 feet. | *Ravalli.* Quartzites, siliceous shales, and shaly sandstones; upper part green and purple; lower part gray, mostly greenish, locally with faint purple tinge; middle part thickest bedded and most quartzitic, consisting locally of fairly pure white quartzite. 8,000 ± feet. | *Kitchener.* Ferruginous quartzite. 7,400 feet. |
| | | *Chamberlain.* Shales, dark bluish, interbedded with sandstone; rusty brown on weathered surface. 3,000 ± feet. | | *Prichard.* Argillite, blue-gray to black, with distinct and regular banding, interbedded with a subordinate amount of gray sandstone. Uppermost part arenaceous and marked with shallow-water features. Base not exposed. 8,000+feet. | *Prichard or Creston formation.* Argillite, dark bluish, banded. 2,000 feet.<br>Sandstones, gray, thick bedded to shaly, interbedded with more or less sandy bluish shales. The rocks become more argillaceous toward the southeast. 10,000 ± feet. | *Creston.* Quartzitic sandstones, thick-platy, gray, interbedded with a subordinate amount of bluish argillaceous material. Base not exposed. 9,500+ feet. |
| *Neihart.* Quartzite, with some shale in upper part. 700 feet.<br>Archean. | | *Neihart.* Quartzite, light colored. Base not exposed. 1,000 + feet. | | | | |

by me between Thompson Falls and Eddy, where the middle beds of the group are more massive than those above and below them. The succession in this region therefore resembles closely that of the corresponding part of the Cœur d'Alene section, but differs from it in that the middle division of the Ravalli "series" is less quartzitic than the Revett formation, of which it is probably the stratigraphic equivalent. The representative of the Ravalli "series" in the Phillipsburg quadrangle consists mostly of quartzite a little less pure than that of the Revett formation, but contains argillaceous beds in its upper portion. No subdivisions corresponding to those in the Cœur d'Alene district are there recognizable.

The rocks beneath the Kitchener quartzite and its equivalents vary still more in thickness and character, but in all sections exhibit certain features in common, which constitute some evidence of their correspondence. They consist in general of indurated sandstones and dark shales, the latter being especially characteristic. The argillaceous constituents predominate in the Cœur d'Alene district to a greater extent, apparently, than in any other locality. Followed westward toward Cœur d'Alene Lake, the shales are seen to become somewhat more arenaceous, and to the north the arenaceous character of the basal sediments becomes still more pronounced. Observations made by me in 1905 were taken to indicate that in general the Prichard formation of the Cœur d'Alene district changes toward the northwest along its strike, into the great mass of medium-grained indurated sandstone designated by Daly the Creston quartzite. In the western part of the Cabinet Range, however, the upper part of this great stratigraphic division displays very typically the prevailing character of the formation as seen in the Cœur d'Alenes. To the southeast, along the Cabinet Range, a somewhat abrupt change in the character of the formation takes place, and in the extensive exposures along the lower part of Flathead River it comprises several thousand feet of dark-bluish argillite that weathers to a rusty color. In more easterly longitudes the rocks presumed to correspond to the Prichard and Creston are not so extensively displayed and apparently show a progressive diminution in thickness. In the Phillipsburg district complex deformation makes it impossible to measure the thickness of the lowest divisions of the Belt group, but the observed aggregate thickness of the Chamberlain and Neihart, whose base, however, is not exposed, is apparently much less than that of the Prichard and Creston in the Cœur d'Alene and Cabinet ranges. In the Belt Mountain section, the only one in the broad region here considered where the base of the Belt group has been observed, the combined thickness of the Chamberlain and Neihart formations is only 2,200 feet.

The beds above the Newland limestone exhibit greater and more irregular variation than those below it. They consist in larger part of shales and flaggy sandstones, here and there passing into quartzites, but include in nearly all sections a well-defined calcareous stratum of variable thickness, correlated by Walcott with the Helena limestone of the Belt Mountain section. The stratigraphy of this upper part of the Belt in the Cabinet Range has not been satisfactorily worked out.

The beds between the two main limestone horizons of the Belt group have a total thickness which ranges, in the sections where they are completely displayed, from 3,800 feet in the northern Rockies to more than 7,000 feet in the Mission Range. They are characterized by red and gray colors, but the proportion and succession of red and gray beds is variable. The limestone formation corresponding to the Helena bears some resemblance to the Newland, in containing considerable ferruginous and siliceous matter and in comprising shaly beds. It is one of the most variable in thickness of all the Belt formations, and its correlative in the Cabinet Mountains was not recognized with certainty. The uppermost part of the series consists in the Mission Range of grayish thin-bedded sandstones, in the Belt region of red shales, and in the Lewis and Livingston ranges of yellow quartzite overlain by red shales. In the central part of the Cabinet Mountains are developed many thousands of feet of shales and sandstones, mostly greenish gray, but in part bluish gray and in part maroon red. The uppermost part of the Phillipsburg section consists of a great thickness of red beds, probably equivalent to the Camp Creek "series" of the Mission Range, but comprising no distinctly calcareous layers.

## DETAILED DESCRIPTION OF FORMATIONS.

### PRICHARD SLATE.

#### DISTRIBUTION AND EXPOSURES.

The Prichard slate, besides being the thickest formation in the Cœur d'Alene district, also has the greatest areal development, and, as may be seen in Pl. II (in pocket), occupies about a third of its surface. Its largest area constitutes most of the northeast quarter of the district. The area second in extent lies north of the South Fork of Cœur d'Alene River, in the west-central portion of the district. There are smaller areas in the Pine Creek basin, on Graham Creek, and along middle and lower Canyon Creek.

The best exposures of the upper part of the Prichard occur about Glidden Pass and west of Sunset Peak. Good outcrops of the lower portions are to be seen on Eagle Creek, south of Murray, and along the South Fork of Cœur d'Alene River east of Kellogg.

The Prichard is important economically as the gold-bearing formation of the district. It is the country rock of the once important mines near Murray, and of other mines, now abandoned, east of Wardner.

#### THICKNESS.

The formation consists of comparatively weak rocks and is less satisfactorily exposed than any other in the district, for, though it does not usually support a heavy vegetation and small outcrops are numerous, it is not displayed in any great cliff sections. As its outcrops are generally not continuous for great distances, its structure can not be worked out in detail. Necessarily, therefore, any estimate of its thickness in this district is a rough one. Probably the most reliable measure of it is to be obtained in the upper part of Butte Gulch, where the exposures are comparatively good and the structure not complex; and the thickness indicated in a cross section along this ravine is more than 8,000 feet. The apparent thickness on the section across the Kellogg area is greater, but there the structure is somewhat more intricate, and the estimate correspondingly less reliable.

Inasmuch as the rocks beneath the Prichard have not been observed within many miles of the Cœur d'Alene district, it is probable that this formation includes a considerable thickness of beds beneath the lowest horizon that reaches the surface within the area here described.

#### LITHOLOGY.

*Megascopic features.*—Owing to the lack of any sufficiently comprehensive and continuous exposure, the succession of strata within the Prichard formation can not be worked out in detail. As the formation is, however, comparatively simple in composition, a detailed section would perhaps serve no purpose that is not answered by a generalized statement regarding the succession, which can be formulated without difficulty.

The bulk of the formation, excepting its uppermost part, consists chiefly of dark argillaceous material, but interbedded with this is a considerable proportion of indurated sandstone which in many places grades into the argillite, while part of it approaches quartzite in character. These arenaceous layers are generally not heavy, but well down in the formation there are thick beds of sandstone, which are especially well exposed in the vicinity of Prichard Creek. From such beds are carved the more prominent hills south and north of Butte Gulch, whence indeed the ravine presumably derives its name. They also give rise to extensive talus slopes northeast of the upper part of Prichard Creek.

Within a few hundred feet of the upper limit of the formation, a fairly rapid though not abrupt change in the character of the beds takes place. The indurated sandstones, sandy shales, and quartzites increase in abundance, and in the uppermost part appears a greenish-gray siliceous shale like that which constitutes the greatest part of the Burke formation. Most significant as indicating the conditions under which these upper beds were laid down is the appearance of such features as ripple marks and sun cracks, indicating deposition in very shallow water and frequent exposure to the atmosphere. The shallow-water features occur throughout the overlying Burke formation, and this fact, as well as the occurrence of gray siliceous shale, like that which mainly composes the Burke, in the upper part of the Prichard, indicates the gradual nature of the transition from the one formation to the other.

This gradual transition naturally causes difficulty in fixing the Burke-Prichard boundaries and necessitates the choosing of some lithologic character which shall consistently be considered as differentiating the two formations. The diagnostic feature of the Prichard is the presence of a considerable amount of blue-gray argillite, for nothing like this typical rock is found in the Burke formation proper except locally and in small amount. By taking this as a criterion it is possible, where exposures are good, to draw the boundary between Prichard and Burke with a precision comparable to the accuracy of the base map.

Of the shaly rocks which predominate in the Prichard formation, the most abundant variety is a dark-bluish argillite of characteristic appearance (Pl. V, *A*). It usually has distinct shaly parting, and its bedding is also marked by a very regular banding in darker and lighter shades of blue-gray. When weathered, this rock is stained along bedding planes and joints with reddish-brown iron oxide. It generally exhibits a slaty cleavage that is fairly distinct but nearly everywhere less pronounced than the shaly parting, which plays the more important part in the disintegration of the rock. As a rule the cleavage is at a considerable angle with the bedding, as may be seen on many weathered joint surfaces which intersect both.

The shaly beds in the upper siliceous part of the formation are rather more sandy and less homogeneous than the rock just described. The lamination is more marked and less regular. Very characteristic of the upper Prichard is a rock made up of dark-blue argillite and whitish arenaceous material, the argillaceous laminæ generally having sun cracks filled with the lighter-colored indurated sand. The upper beds also comprise considerable greenish-gray fine-grained siliceous shale and indurated flaggy sericitic quartzite, which, as they are abundant in the overlying Burke formation and will be described in connection with it, need not receive further attention here.

The most typical phase of the arenaceous material interbedded with the argillites is a fine-grained, compact, indurated sandstone, usually in rather thin beds. When taken fresh from underground workings this rock is bluish or greenish gray, but when slightly weathered it is brownish gray, and surfaces long exposed to the weather become bleached. This sandstone rarely shows noticeable cleavage.

From this dominant type there are gradations into quartzite on the one hand, and into the blue argillite already described on the other. The rock just described is found by microscopic study to contain, in addition to quartz, considerable feldspar, mica, and argillaceous material. By diminution in these constituents, it approaches a quartzite which is whiter and harder, and generally not so fine grained, though nowhere coarse. The transition to clay slate is through gray indurated sandy shales and shaly sandstones, which, as compared with the more argillaceous rocks, are thicker bedded, less distinctly banded, and harder, while they also show slaty cleavage less distinctly.

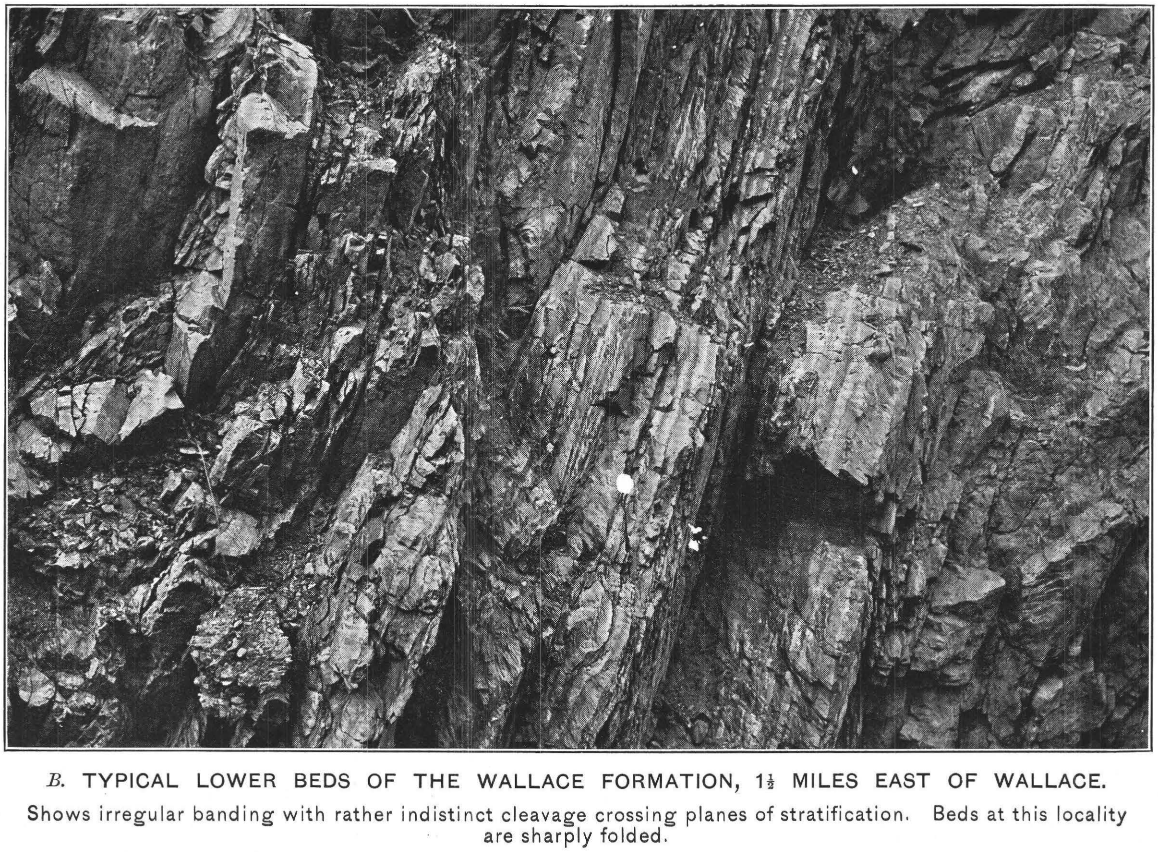
Features characteristic of sediments laid down in extremely shallow water and exposed occasionally to the atmosphere were in this region first abundantly developed in the upper part of the Prichard formation. As they occur in profusion in nearly all the later formations, it may be well to present the following brief general description, which will serve readers unfamiliar with them for elucidation of many references in the pages devoted to the other stratigraphic units.

These features comprise ripple marks, sun cracks, and rain pits, which are described in many text-books, and other features, less commonly noticed in the literature, designated here "mud breccias" and "pseudoconglomerates."

Ripple marks appear as rounded ridges half an inch to an inch in width, separated by narrow grooves, and give a peculiar corrugated appearance (see Pl. VI, *A*, p. 34) to slabs of sandstone split parallel to the bedding. They are formed by the drag of the undertow on gently sloping beaches, or by currents in shallow water.

*A.* PRICHARD SLATE NEAR MOUTH OF ELK CREEK.

Shows the regular bedding and banding with characteristic joint planes nearly at right angles with the bedding. Cleavage is here parallel to the planes of stratification.



*B.* TYPICAL LOWER BEDS OF THE WALLACE FORMATION, 1½ MILES EAST OF WALLACE.

Shows irregular banding with rather indistinct cleavage crossing planes of stratification. Beds at this locality are sharply folded.

Sun cracks, or mud cracks, appear on slabs of shaly sandstone or sandy shale as veinlike markings crossing one another irregularly. They are produced when mud exposed to the action of the sun becomes partly dried at the surface and cracks because of shrinkage. When the flats are submerged again they become covered with a layer of sediment which fills the cracks and which being generally of a different color from the fissured mud, helps to make these features easily recognizable on planes of bedding or on joint planes that cut across the strata.

Certain small, round, shallow pittings in the surfaces of sandstone slabs are accounted for as impressions of the raindrops of a light shower passing while the soft sediments were exposed to the air; at the next submergence they became covered with a layer of mud and are thus preserved intact for an indefinite time. These have been found only in the St. Regis formation.

To certain rocks containing angular or slightly rounded fragments of fine-grained argillite embedded in somewhat coarser-grained and more arenaceous material the term "mud breccia" may be given. This structure shows most clearly on weathered surfaces. The mud breccias are generally found in association with sun cracks, and the angular fragments are supposed to be broken off from the edges of flakes of mud curled up by drying in the sun. These rocks come under Walcott's definition of "intraformational conglomerate,"[a] but constitute a variety not observed by him.

"Pseudoconglomerate" is a term provisionally applied to certain rocks found near the upper limit of the Prichard formation at the mouth of French Gulch. The beds there exposed exhibit all the marks of shallow-water origin, and include some rocks made up chiefly of flattened, very rudely ellipsoidal masses half an inch to 3 inches in diameter. These masses have somewhat the aspect of flat pebbles, but their lithologic character clearly indicates that they are not pebbles in the ordinary sense of the term. They are composed mainly of compact fine-grained sandstone, and on the faces of slabs split parallel to the bedding are covered with a thin film of fine, dark argillitic material. The interstices between them are filled with this dark argillite, which also forms discontinuous films within the ellipsoidal masses. There are no pebbles or other fragments of foreign material in these rocks. It appears that they must have been formed on a sloping shore by the waves rolling up masses of water-soaked sand which became flattened horizontally by their own weight.

*Microscopic features.*—The mineralogical composition of the Prichard sediments is fairly constant qualitatively, and is most readily determined in microscopic thin sections of the indurated sandstones. These rocks are found to consist of grains that are angular to subangular in outline and somewhat variable in size, with an abundant cement filling completely all the original pore spaces. Of the original grains, the great majority are of quartz, but there are also many of feldspar, and the larger particles of the muscovite that is present are also probably of detrital origin. Interstitial between the particles that are sufficiently large to stand out clearly there is much very fine grained material consisting chiefly of sericite and quartz, mingled with minute opaque particles. Part of this mixture doubtless represents the fine mud that in the working over of the sands of which these rocks were made was not completely washed away from the coarser grains, but it probably includes also much secondary material.

As might be expected, the composition of the finer-grained rocks differs from that of the coarser chiefly in that the former contain a larger proportion of mica. Under the microscope most thin sections of the argillites show alternate layers of different fineness. In the coarser there are conspicuous grains of quartz and feldspar, irregular in form and size, embedded in a very fine grained paste consisting mainly of sericite and quartz, with the former apparently the more abundant. The finest layers consist of a turbid, almost cryptocrystalline quartz-sericite mixture; some chlorite also occurs but it is not prominent and it is apt to be overlooked. Opaque dust, probably carbonaceous, occurs most abundantly in the finest material.

Probably the chief petrographic interest of these rocks pertains to certain of their minor constituents. Every slide contains numerous cloudy, whitish particles which, as Lindgren[b] has shown, are probably of titanic acid, a conclusion confirmed by the occasional occurrence

[a] Walcott, C. D. Palæozoic intraformational conglomerates: Bull. Geol. Soc. America, vol. 5, 1894, pp. 191-198.
[b] Metasomatic processes in fissure veins: Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 604.

of minute prisms of rutile on their borders. Rutile in isolated individuals is also visible with high magnification in most specimens. Zircon is common in small irregular grains and prisms which generally appear waterworn, so that this mineral, for the most part at least, is probably clastic. Certain other minerals, however, which occur isolated or in small clusters, are evidently of totally different origin. Of these tourmaline occurs in nearly every slide; siderite in most; pyrite, magnetite, biotite, and chlorite in many; and calcite in a few. The mode of occurrence of these minerals, characteristic of the region rather than of the formation, is remarkable in that they commonly form individuals much larger than the clastic grains and bounded more or less completely by crystal faces which cut across the latter. It is evident that they have been formed through metasomatic replacement of the sedimentary material by substances contained in liquid or gaseous solution. In general, tourmaline, magnetite, and pyrite are more nearly idiomorphic than the other minerals. All of them tend to assume more perfect crystal form in the finer-grained rocks than in the coarser ones, probably because the sericitic material is more readily replaced than the quartz. The occurrence of some of these minerals in its bearing on ore deposition is further discussed by Mr. Ransome on pages 95, 97, and 101.

*Distinctive characteristics.*—The Prichard formation can hardly be confused in the field with any other. The regularly banded argillite which forms the greatest part of it is extremely characteristic and easily recognized. Certain phases of the upper part of the Wallace formation somewhat resemble it, but confusion is readily avoided even here by remembering, first, that the Prichard nearly always weathers in dark reddish brown hues, in contrast to the yellow tints characterizing weathered Wallace rocks, and, second, that calcareous material, more or less abundant in the Wallace, is quite absent from the Prichard formation.

### BURKE FORMATION.

#### DISTRIBUTION AND EXPOSURES.

The Burke formation is so named because of its extensive development about Burke, where it forms the country rock of the important mines. Its areal development within the district is large, and because of the strength of the rocks of which it is composed it forms many peaks and ridges, and is exposed in many cliff sections. Large areas are present near the northeast corner of the quadrangle, and in the northwestern part, where it forms the hills between the forks of Cœur d'Alene River, but it is most extensively and clearly exposed in the area that is crossed by Canyon Creek and extends eastward into Montana. The best exposures are probably those in the amphitheater that incloses Lower Glidden Lake. The steep glaciated walls, stripped of forest growth by fire, show the edges of the entire formation and afford opportunity to study the lithology of the beds in detail. Good exposures occur, however, in all parts of the district, so that certain horizontal variations may be traced, though not continuously.

#### THICKNESS.

Probably the most reliable estimate of the thickness of this formation is afforded by a measurement across the strike near the Glidden Lakes, for here the attitude is fairly constant and there is no evidence of faulting. The value obtained is about 2,000 feet.

#### LITHOLOGY.

*Megascopic features.*—The Burke formation is composed of rocks that show all gradations from nearly pure quartzite to siliceous shale. The quartzite beds are relatively more abundant in the upper part of the formation; the lower part is more shaly. The upper and lower parts thus approach the Revett and Prichard, respectively, in lithologic character, and the Burke, therefore, well exemplifies the fact that the formations of the Belt group generally grade into one another. The proportion of quartzite in the higher beds of the formation also becomes gradually larger from west to east, and beyond the limits of the district in that direction this change, proceeding concurrently with a decrease in the purity of the Revett quartzite, obscures the distinction between Burke and Revett.

Even in the Cœur d'Alene district the gradual passage from the Burke formation to the Revett quartzite causes a difficulty in fixing a precise boundary much greater than that which is experienced in delimiting the Burke from the Prichard, for in the present case we have no definite criterion such as the presence or absence of a particular kind of rock. Quartzites like those of the Revett occur in the Burke, and quartz-sericite rocks like the typical Burke occur, though in subordinate amount, in the Revett formation. The boundary has been placed at the horizon where the fairly pure quartzite begins to preponderate markedly over the softer mudstones. Even where exposures are good, the line might not be drawn by a given observer precisely at the same horizon in different places and at different times, nor would two observers be apt to agree precisely as to where the boundary should be placed in a given section. In areas where exposures are poor the difficulty is evidently much greater, for the outcrops and the float in the upper part of the Burke would contain an undue proportion of the quartzite, which would resist weathering more than the other rocks. The boundaries between Burke and Revett are therefore admittedly rough, and where the structure is complex, as in the vicinity of Wardner and at places along Canyon Creek, they may be considerably in error.

The lithology of the Burke formation is well illustrated by the following descriptive section of its upper part, measured on the slope west of Lower Glidden Lake. The beds are described in descending order, and the section includes some of the overlying Revett quartzite, to show the character of the transition between the two formations.

*Section on west side of canyon below Lower Glidden Lake.*

| | Feet. |
|---|---|
| Quartzite and siliceous sandstone, mostly pale greenish, finely banded or cross-bedded, generally speckled with red | 600 |
| Gray-green fine sandstone with a bed of white quartzite interbedded—the sandstone grading downward into greenish cross-bedded quartzite | 75 |
| Pure white quartzite | 8 |
| Gray-green quartzite grading into gray-green banded fine sandstone | 12 |
| Greenish fine-grained cross-bedded quartzite | 30 |
| Greenish fine-grained quartzitic sandstone | 30 |
| No exposures—talus greenish-white quartzite, speckled and in part finely cross-bedded | 20 |
| Greenish and purplish-gray fine siliceous sandstone, grading into white quartzite, generally speckled | 190 |
| Unexposed | 10 |
| Light greenish-gray fine sandstone grading into quartzite | 42 |
| Unexposed | 15 |
| Top of Burke formation. | |
| Dark-gray indurated sandy shale | 10 |
| Gray mudstone and green sandstone interbedded | 8 |
| Light to dark gray mudstone | 177 |
| White quartzite interbedded with gray mudstone, in beds 2 to 6 feet thick | 10 |
| Laminated gray-green mudstone with ocher-red stripes on weathered surface | 12 |
| Quartzite | 5 |
| Gray mudstones, weathering light, in places banded with red and fluted on weathered surfaces | 140 |
| Dark-gray mudstones | 30 |
| Gray and gray-green hard mudstones, rather dark, with a little purplish-gray quartzite interbedded in thin layers | 110 |
| Purple-gray quartzite | 5 |
| Gray and gray-green mudstones, rather lighter colored than those above, here and there grading into purplish-gray quartzite, which forms thin beds | 45 |
| Unexposed (glacial bench) | 170 |
| Light-gray siliceous mudstones, weathering whitish, interbedded with some grayish-purple speckled quartzite, the two rocks grading into each other | 40 |
| Unexposed | 15 |
| Green mudstones, not hard, fluted and striped on weathered surface, sun cracked | 10 |
| Vitreous purplish quartzite and light-greenish mudstones, interbedded in layers about 2 feet thick, the two rocks grading into one another | 10 |
| Fine, somewhat flaggy gray-green mudstones, obscurely banded, moderately hard | 60 |
| | 1, 850 |

In this section the most abundant rocks are fine-grained flaggy siliceous sediments, mostly light colored. The bedding is marked by shaly parting and by obscure color banding. The typical siliceous mudstones are mostly pale greenish gray, though part of them are of a rather dark tint. Less common is a light-purplish hue, and there is in some beds an alternation of purple and green layers. Brighter tints of green and purple occur, but are rather rare. The essential constituents of these rocks (as microscopic study shows) are quartz and sericite. Some of the sericite is visible to the naked eye, but for the most part it is so finely divided that it can be seen only with the aid of the microscope. The abundance of this mica makes the rock much softer than pure quartzite, and it is easily scratched by the pick.

In many places gradual transitions are traceable from the soft shaly rock through massive pale-green sericitic quartzite to hard white quartzite, such as constitutes most of the overlying formation. This rock is especially abundant in the upper part of the Burke, which shows the gradual nature of the transition to the Revett quartzite.

More abundant and characteristic, however, than the white quartzite is a fine-grained grayish-purple quartzite or quartzitic sandstone, as a rule finely but indistinctly banded parallel to the bedding. In the Glidden Lake section this occurs in moderate amount. The proportion which it bears to the other Burke rocks varies widely, however, in different parts of the district. To the west of Burke none of it has been noticed, but to the east it distinctly increases in abundance. In the section along the divide southeast of Granite Peak it is more abundant than in the Glidden basin, and along the eastern edge of the district it is still more so. On the ridge at the head of Bear Gulch, and near the point where Prospect Creek leaves the district, the Burke, for several hundred feet from its upper surface, consists mainly of banded purple quartzite. It might be questioned whether some or all of this rock should not be mapped as Revett, but the course adopted seems to be justified by the fact that it is interbedded with rocks more characteristic of the Burke, while it is not found in the main body of the Revett quartzite. There is thus a gradual increase in the proportion of purple quartzite in the Burke from west to east.

The most interesting characteristics of the Burke rocks are the universally present shallow-water features (Pl. VI, *A*). Sun cracks and ripple marks are seen in almost every outcrop, and show clearly that the formation was deposited in an area where the water was shallow and the moist sediments were frequently exposed to the air.

*Microscopic features.*—The microscopic character of the typical Burke mudstone hardly requires much description, as the rock resembles, more closely than its megascopic appearance would indicate, the typical Prichard slate. From this rock it differs chiefly in containing a smaller amount of carbonaceous dust. The accessory constituents are the same, but biotite, chlorite, and magnetite attain more perfect development in some localities. The Burke quartz-sericite rocks are also somewhat more siliceous than the Prichard slates.

In the coarser-grained and thicker-bedded sediments of this formation the microscope shows rather angular grains of quartz and feldspar, and flakes of presumably clastic mica in an abundant sericitic paste. By diminution of the cement this passes into a fairly pure quartzite approaching that found in the Revett formation. In the sericitic quartzite the schistosity is marked by parallel arrangement of the flakes of sericite. Much of the quartz and sericite in these rocks is secondary, and some specimens show clear examples of the secondary enlargement of quartz grains, the boundaries of the clastic particles being marked by minute inclusions outside of which secondary quartz has been deposited with the same optical orientation as the nucleus.

*Distinctive characteristics.*—The Burke formation has not so marked an individuality as some of the others in this region. Where it is well exposed, it is readily distinguished from the formations above and below. Two younger formations, however, the St. Regis and the Striped Peak, are very similar to it lithologically, but both of these are characterized by brighter tints of purple and green than are found in the Burke, and there is little danger of confusing them with it even where the structural relations are not clear.

*A.* RIPPLE MARKS IN BURKE FORMATION ON TIGER PEAK.

*B.* BENCH GRAVELS NEAR MURRAY, LOOKING WEST FROM ALDER GULCH.

Shows old hydraulic workings and the relation of the gravels to Prichard Creek, just visible at the left of the illustration.

### REVETT QUARTZITE.

#### DISTRIBUTION AND EXPOSURES.

The Revett quartzite, being strongly resistant to erosion and giving rise to a scanty and infertile soil, is generally carved into prominent and rugged features and is well exposed. In the western part of the district it is well displayed on Kellogg Peak and in the drainage basin of Pine Creek; less representative exposures occur about Wardner and on the hills across the river to the north. Excellent sections are exposed in the canyon of Big Creek just above its lowest forks, and extensive outcrops occur along the high ridge south of Gem and Burke. The best exposures of this, as of the underlying formations, occur, however, in the structurally simple eastern part of the quadrangle. The quartzite forms steep glaciated escarpments about the heads of Beaver and Twentytwo Mile creeks in Montana, and along the eastern side of the ridge extending southward from Granite Peak. The precipitous eastern face of this peak—unfortunately misnamed—overlooks Revett Lake, whose name has been taken to designate the formation.

#### THICKNESS.

The thickness of the Revett quartzite in the section west of Glidden Lake and that on the west side of Twentytwo Mile Creek is 1,000 to 1,200 feet. In the western part of the district the areal distribution of the formation indicates that it is considerably thicker, but here the structure is complex, and it is therefore difficult to determine the thickness exactly. The study of the region to the north and east has shown, however, that the Revett quartzite is less persistent than the formations above and below, so that there is nothing improbable in the supposition that within the boundaries of this district the Revett quartzite thins out to the east.

#### LITHOLOGY.

*Megascopic features.*—The Revett formation is lithologically the simplest and most homogeneous of the Cœur d'Alene sediments. The larger part consists of hard, pure, rather thick-bedded quartzite, but there is also a minor proportion of rocks less purely siliceous. It contains, however, no distinctly argillaceous nor any calcareous layers.

Successive layers of the formation from base to top show variations in character which seem to hold good throughout the district. There is a gradual passage from the Burke formation to the typical Revett, which has already been described. Even the thickest and coarsest-grained quartzitic beds of this lower part are noticeably impure and sericitic and are interbedded with gray-green shaly layers. The lower strata mapped as Revett are intermediate in character between the Burke and the beds of purer quartzite which form the middle part of the formation. Still higher these pass again into more sericitic, thinner-bedded quartzites, partly sun cracked and ripple-marked, which are transitional between the massive quartzites and the colored sandy shales that constitute the overlying St. Regis formation. The Revett formation thus comprises a central portion largely of pure quartzite, passing into less purely siliceous beds above and below, which are transitional to the overlying and underlying formations.

The rock most characteristic of the Revett formation is the massive quartzite. The purest material of this character forms rather thick beds, breaking down on steep slopes into blocks bounded by smooth joint planes. Some of the purest of the quartzite is almost snowy white, but most of it is faintly tinged with green, and some is of a very pale rose color. The bedding is commonly marked by fine delicate banding. The texture is invariably rather fine and quite compact, and the purest material is so hard that it can not be scratched with steel. Its fracture is conchoidal, the fresh surface has a somewhat vitreous appearance, and thin chips are translucent.

Even the massive beds, however, are made up in greater part of material less pure than that above described, the chief impurity being sericite. The presence of this mineral shows itself megascopically by the appearance of a pale-green tint and a lower degree of hardness, and some of it can be recognized by the aid of a good pocket lens. The impure quartzite is duller and has a rougher fracture than the pure. Lamination is more common and more distinct in these sericitic quartzites than in the purer ones; it is in many places parallel to the stratification, but in others, especially near the base of the formation, shows the cross-bedded structure.

The impure quartzites grade into rocks which can hardly be called quartzite. The lower part of the formation contains a good deal of brownish-gray banded siliceous indurated sandstone. In all parts of the formation are scattered thin beds of a soft greenish fine-grained sandstone composed apparently in greater part of finely divided white mica, and near its upper and lower limits are beds of siliceous shale like that which constitutes most of the Burke.

Ripple marks, though found in the upper and lower parts of the formation, do not occur in the more massive quartzites of the central part.

Mountain-making forces affect these quartzites less conspicuously than the softer rocks of the underlying formations. Slaty cleavage is not generally seen in the purest quartzite. The development of schistosity seems, however, to be greatly facilitated by the presence in the original sediment of even a small amount of argillaceous material, which under the influence of metamorphic agencies becomes converted to sericite. In the neighborhood of Burke, where dynamic action seems to have been most intense, the Revett quartzites almost all show rude cleavage. Even in the purest rock irregular partings are locally developed, the surfaces of parting being covered by thin films of sericite. In the less disturbed eastern portion of the district, cleavage is rarely noticeable in the quartzite, which is divided into smooth and regular blocks by the joint planes.

A conspicuous and unusual feature of much of the Revett quartzite, especially in the areas contiguous to Canyon Creek, is the presence of numerous specks of iron oxide, generally about 2 millimeters or less in diameter. These are not visible in perfectly fresh rocks from mines, but they appear in fragments that have been exposed to the weather even for a few weeks. They are produced, as microscopic study proves, by the decomposition of disseminated crystals of siderite.

*Microscopic features.*—The microscopic features of the argillaceous quartz-sericite rocks and micaceous sandstones of this formation will not be described here, as they are similar to those of rocks found in the Prichard and Burke. Only the purest quartzite, which occurs in no other formation, need be noticed particularly. Its minute structure is easily made out under the microscope, owing to the comparative scarcity of fine-grained turbid material.

The clastic grains are subangular to rounded in form, except where they are modified secondarily in a manner presently to be described. They consist mainly of quartz, but a little feldspar and apparently clastic muscovite are present in all specimens, and nearly every slide contains particles that appear to be detrital fragments of fine sericitic slaty rock, though they may partly represent interstitial mud. The cement, which contains a large proportion of sericite mixed with a little quartz, is small in amount and fills minute polygonal spaces and thin streaks between the grains. Very commonly, however, the individual grains fit closely together as in a mosaic, separated by little or no sericitic material, and it is quite evident that in such places the clastic grains have grown by the addition of quartz in parallel orientation, although their original boundaries are rarely made visible by inclusions.

The constituents that appear in subordinate rôles in the argillites and graywackes are found in the quartzites, but in general are even less abundant. Zircon and magnetite form sparingly disseminated moderate-sized grains, rutile is scarce, and tourmaline occurs in larger but less numerous individuals than in the fine quartz-sericite rocks. It forms blunter and less perfectly developed prisms than in those rocks, or even mere ragged grains. Siderite is locally developed in numerous comparatively large imperfect rhombohedra, its secondary nature and the manner of its growth being plainly visible.

Evidence of pressure is generally afforded by undulatory extinctions in the quartz grains. In the more sericitic specimens a schistosity is developed which is expressed by the parallel arrangement of the sericite flakes.

## ST. REGIS FORMATION.

### DISTRIBUTION AND EXPOSURES.

The St. Regis formation, although the thinnest one of the series, has a rather disproportionately large areal development. This is probably due mainly to two facts—first, that the indurated shales and sandstones composing it are strongly resistant to erosion, and, second, that it is overlain by the easily eroded shales of the Wallace formation. Its most extensive area within the quadrangle is that in the southeastern part, which includes the pass, a part of the mountain ridge, and some of the headwater tributaries of the stream, to which the name St. Regis has been given, and this name is therefore taken to designate the formation. It is not in this area, however, that the St. Regis rocks are best exposed. Complete cliff sections, with portions of the underlying and overlying formations, occur at the head of Military Gulch, and in Maple Cliff and Castle Rock on the North Fork of Cœur d'Alene River.

### THICKNESS.

From these favorable sections good estimates for the thickness of the formation are obtained, which give a value of about 1,000 feet, but it appears to be thicker on Willow Creek and farther east.

### LITHOLOGY.

*Megascopic features.*—The Military Gulch section has been studied in detail, and from it the following descriptive section has been compiled:

*Section of St. Regis formation at head of Military Gulch.*

| | Feet. |
|---|---|
| Green-banded, very fine mudstone, partly sun cracked and ripple-marked, with some green calcareous material, weathering ocherous (Wallace formation) | 70 |
| Top of St. Regis formation. | |
| Purple shaly sandstone, with sun cracks and ripple marks | 120 |
| Two beds of fine green sediment showing slaty cleavage, separated by a bed of purple sandstone | 6 |
| Shaly sandstone and sandy shale, mainly purple, interlaminated with green, with a few thin beds of calcareous material near the base | 140 |
| Hard grayish-purple quartzite interbedded with green and purple shaly sandstone | 25 |
| Purple, irregularly laminated shaly sandstone, with thin beds of purplish-gray quartzite | 20 |
| Green and purple, finely laminated shaly sandstone, with purple quartzitic sandstone and quartzite | 100 |
| Fine green mudstones and shaly sandstones, with some quartzitic layers, ripple marks, etc | 80 |
| Purple sandstone | 3 |
| Green sandstone | 3 |
| Purple shaly sandstone, with interbedded layers of purplish-gray quartzite | 80 |
| Unexposed | 60 |
| Green and purple laminated sandstone | 6 |
| Impure limestone, weathering vesicular | 3 |
| Purple and purplish-gray banded shaly sandstone | 30 |
| Unexposed | 40 |
| Grayish-purple fine siliceous sandstone and quartzite, partly laminated, with some thin beds of red-speckled white quartzite | 180 |
| Massive-bedded fine-grained purplish-gray quartzite with a few interbedded whitish layers. Both kinds red speckled | 100 |
| Base of St. Regis formation. Revett quartzite below. | |
| Total thickness of St. Regis formation | 996 |
| Green sandstone, shaly, ripple-marked | 10 |
| White quartzite | 8 |
| Unexposed | 15 |
| White quartzite | 15 |
| Greenish flaggy sediments | 15 |
| Pure-white quartzite with red specks in weathered portion | 10 |

Attention may be called briefly to the most characteristic features of the St. Regis rocks in this section. The prevailing colors are rather bright tints of green and purple, the latter color somewhat predominating. As regards texture, the beds consist mainly of rather fine-grained materials. Some brittle green mudstones of extremely fine horny consistency are present, but the rocks which constitute the greater part of the formation are built up of thin alternating layers of argillaceous and arenaceous material. There are coarser-grained and thicker beds of quartzitic material, consisting for the most part of a purplish quartzitic sandstone, but including also a little white quartzite. Both the last-named rocks are more abundant in the lower than in the upper part of the formation. The white quartzite is found only near the base, and its presence indicates a transition, comparatively abrupt, into the main body of white quartzite. Of rare occurrence are thin beds of calcareous material that weathers to an ocherous color. The characteristic of the formation which throws most light on the manner of its accumulation is the general presence of shallow-water features.

The Military Gulch section well illustrates the usual character of the St. Regis formation, and the exposures on North Fork and west of Twentytwo Mile Creek show an assemblage of rocks essentially similar to that just described. In some other localities, however, the St. Regis differs materially from the Military Gulch facies. This fact is illustrated by exposures on Boulder, Willow, and Deer creeks and on St. Regis River.

Boulder Creek has exposed a peculiarly interesting section. On the eastern side of the canyon, about a mile and a half from the mouth, there are bold outcrops of light-colored siliceous rocks which are overlain by purple and green beds like the typical St. Regis, and which thus apparently occupy the position of the Revett quartzite. They are shaly, however, and marked in part by shallow-water features, so that they resemble the Revett quartzite less than the St. Regis, with which they are accordingly mapped. These beds appear, less well exposed, higher up the canyon. Certain of them have a peculiar conglomeratic structure. They show, in an abundant matrix of quartz and sericite, numerous roundish to subangular fragments which do not differ very greatly in constitution from the matrix. These fragments consist of siliceous material, in part fairly pure quartzite, in part gray sericitic quartzite, and in part fine-grained, dark-green, apparently chloritic rock. Rocks similar to all of them are found in the ordinary facies of the St. Regis formation. Some of them are impregnated with iron oxide, which makes them conspicuous in the lighter groundmass. These conglomeratic beds are of remarkably small extent, and are not seen west of Boulder Creek. An outcrop was noted on the west side of Willow Creek canyon, but they were not seen elsewhere in the quadrangle.

The origin of these peculiar rocks is not obvious, and three hypotheses have been considered as possible explanations—first, that they are friction breccias; second, that they are true conglomerates; and third, that they are intraformational conglomerates. The last explanation is believed to be the true one. It is supposed that in the vast mud flats upon which the St. Regis beds were being laid down the surface was raised up into a low dome of small extent, upon which the soft strata were exposed to wave action, and fragments were broken away and incorporated with the soft siliceous mud that was accumulating in the surrounding waters.

In the Willow Creek section a great thickness of St. Regis beds is exposed, and the lower part crops out boldly on the east side just south of the Stevens Peak tunnel. On the lower part of the slope about 550 feet of fine-grained green-banded rocks are exposed, with a few thin beds of calcareous material, very similar to the typical lower Wallace. Only at one level in this thickness were a few lavender bands noted. Above these beds are purple and green shaly sandstones like those of the typical St. Regis. The total thickness of the section here is apparently greater than at Military Gulch, but the exposures are not complete enough to make the estimate reliable.

North of Borax, near the southeast corner of the district, there are fairly good exposures showing, as on Willow Creek, some hundreds of feet of gray-green shales overlain by purple and green beds. On Gold Creek these lower greenish shales appear, and are in part very quartzitic. The Hunter mines also are in shaly quartz-sericite rocks associated on the surface with purple beds which do not appear underground. Their position and lithology indicate that they belong to the St. Regis formation.

The section along Deer Creek also is exceptional. Its thickness is normal, but it consists almost entirely of green siliceous shales, with only scattered purplish bands and none of the characteristic deep-purple color.

In the southeastern part of the district and down the valley of St. Regis River the formation appears to contain a greater amount of green as compared with purple and to have a greater thickness than is usual in the district as a whole. As exposures in this vicinity are poor, however, and as the structure is complex they do not afford a basis for a satisfactory measurement of the strata.

The St. Regis rocks are fairly susceptible to change by mountain-making forces, and are in many places distinctly slaty. In the less disturbed areas, however, they are divided by jointing into massive blocks.

*Microscopic features.*—When studied microscopically, the rocks of the St. Regis formation show few characters not illustrated by rocks of lower formations and already described. The sandstones are made up of subangular grains of quartz, feldspar, and perhaps of some fine-grained slaty rock, and flakes of mica, with much fine interstitial material representing in part original mud and in part secondary cement. The medium-grained siliceous sandstones grade into fine-grained quartz-sericite slates. The same minor accessories (rutile, zircon, tourmaline, etc.) occur as in the older rocks, and the schistose structure is well illustrated in many specimens.

The characteristic purple and green colors are found to be due to hematite dust and chlorite, respectively. The hematite seems to be in large part of the specularite variety; some is quite opaque in thin sections, but here and there transparent thin hexagonal scales of blood-red micaceous hematite occur. The chlorite in some specimens is finely divided and evenly distributed like the sericite, but in a few specimens it forms nests composed of larger individuals. In a bed of very deep-green, rather fine-grained material cropping out a little north of the Boulder Creek fault, the cement is nearly all chlorite, and no sericite whatever is found. There is some reason to think that the chlorite here was formed by some secondary agency which acted locally.

## WALLACE FORMATION.

### DISTRIBUTION AND EXPOSURES.

The Wallace formation has very extensive areal development in the Cœur d'Alene district. The largest area occupies the greatest part of the southern third of the district. It forms the entire crest of the ridge extending from Placer Creek southeastward, the greater part of the Placer Creek and Big Creek basins, and a belt extending along the southern slope of the river valley from Placer Creek to Milo Creek. A considerable area lies north and east of Mullan. A large part of the Beaver Creek basin is carved in a belt of Wallace rocks which dip gently eastward and are bounded on the east by the great Dobson Pass fault. Another strip, bounded within the district by two great converging faults between which it has dropped down, lies east of Eagle, and the southern border of what is presumably an extensive area appears in the extreme northwestern part of the district.

This accumulation of shaly rocks is the least resistant to erosion of all of the Cœur d'Alene formations, and is on the whole not well exposed. Rather remarkably, however, the highest summit of the quadrangle (Stevens Peak) is carved from Wallace rocks. The glaciated northern faces of this peak and of other elevations to the east give the best exposures of all but the uppermost part of the formation. The highest beds are well exposed in the Big Creek basin, at the head of the west fork of Placer Creek, and east of Beaver Creek.

### THICKNESS.

The Stevens Peak exposure shows a greater thickness of the Wallace beds than is displayed continuously at any other locality in the district. Going northward from the summit one crosses a thickness of typical Wallace beds apparently amounting to about 2,500 feet. The conditions of exposure are such as to make it almost certain that the apparent thickness of the formation is not increased by faulting; but allowance should be made for the thickening of the beds by minute folds. Twenty per cent seems a sufficient allowance for this factor, which would make the corrected thickness at Stevens Peak 2,000 feet. But at this locality a great part of the formation has been eroded away, and to the southwest of the peak within this district, there are beds stratigraphically higher, although not well enough exposed for measurement. The next overlying formation, the Striped Peak, is not exposed within many miles. In the headwaters of Placer Creek and Big Creek there are exposed about 2,000 feet of Wallace from the Striped Peak down, which are thought to be stratigraphically higher than the beds that form the top of Stevens Peak, for they differ somewhat lithologically from the beds visible in the Stevens Peak section. After considering these facts and making various trial sections across the wide areas of Wallace rocks, I have concluded that the formation can hardly be less than 4,000 feet thick.

LITHOLOGY.

*Megascopic features.*—The Wallace formation is lithologically the most heterogeneous in the Cœur d'Alene section, and comprises rocks that differ widely from one another in composition and appearance. It might under better conditions of exposure be divided into two or three formations, but under existing conditions this is impossible. On the other hand, almost all the rocks of the Wallace formation have in common a notable content of the carbonates of magnesium and lime which distinguishes them from those of all the other formations of the district.

The formation as a whole is an assemblage of thin-bedded fine-grained rocks, including calcareous quartzites, impure limestones, and shales that are in great part calcareous, all marked by such features as mud cracks and ripple marks, which prove that they were deposited on vast mud flats frequently exposed to solar radiation.

The vertical variations in the formation, though not sufficient to afford a practical basis for subdivision, hold good throughout the district and are sufficiently well marked to afford the observer who is familiar with them a means of judging, even from the float, in any area of Wallace rocks what part of the formation is under foot.

The lowermost part is characterized by a predominance of gray-green slaty rock, which is in large part calcareous or dolomitic. If one passes across the strike to higher and higher beds, one finds thin beds of calcareous sandstone or quartzite appearing and becoming more common, while impure limestones, recognized by their mode of weathering, become numerous. Still higher, there are added to these materials thin beds of blue-gray argillite somewhat like that which predominates in the Prichard, and the calcareous layers, which weather reddish yellow, are mostly blue-gray on fresh fracture. This middle part of the formation is the most heterogeneous, and in weathered outcrops is characterized by a striking banded appearance, shown in Pl. V, *B* (p. 30), due to the frequent alternation of beds of white sandstone, yellow weathered limestone, and greenish and bluish argillite, whose thickness is generally but a few inches.

Higher up in the column the sandstone beds disappear and shale becomes strongly dominant. The most characteristic rock of the uppermost part of the formation is a blue-gray, finely laminated, somewhat calcareous argillite, well exposed along the road opposite Beaver Station, on West Fork of Placer Creek, and along the crest of the St. Joe Mountains east of Striped Peak. Locally this material is interlaminated with very thin layers of impure limestone, weathering yellow. The upper division also contains a large amount of greenish-gray dolomitic slate of waxy texture, similar to that which predominates in the basal beds.

If a threefold separation could be made on lithologic grounds, it would be into a lower division mainly of green slate, a middle division of bluish and greenish argillites, limestone, and calcareous quartzite, and an upper one of bluish and greenish argillites, more or less calcareous, without the white beds of calcareous quartzite that characterize the middle division.

At the top the Wallace passes into the overlying Striped Peak formation by a fairly rapid gradation, which may best be observed at the head of West Fork of Placer Creek. The transitional rocks are very thin bedded sandy shales, which within a short distance pass into the flaggy sandstones of Striped Peak. The dividing line may perhaps be fixed most logically by considering the highest calcareous beds as Wallace and all above them as belonging to the Striped Peak formation, the body of which is free from limy material.

The general succession of rocks within the formation having been outlined, it is in order to proceed to a more particular description of the varieties of which it is composed.

The typical rock of the lowermost division is a very fine grained sediment of gray-green color, generally banded in lighter and darker layers (Pl. V, *B*), but forming rather massive beds. Some of the beds are of a fairly bright green color, but weather almost white. The material is soft enough to be scratched easily with steel, is translucent on thin edges, and has a characteristic "horny" appearance. Its chief constituents, as is found by microscopic study, are quartz and sericite. Much of this rock, however, when weathered becomes coated with a thin film of limonite, that indicates the presence of a ferruginous carbonate, a few weeks exposure on the dump of a prospect sufficing for the development of this yellow stain.

The limonite specks derived from large grains of weathered siderite are not so frequently seen in these rocks as in those of the lower formations, but in some places the green slate shows abundant crystals of siderite a few millimeters in diameter and exceptionally perfect in form. Probably the main portion of the finely divided carbonate is dolomite, though the presence of some calcite is indicated by slight effervescence with cold dilute hydrochloric acid.

The green quartz-sericite slates pass by all gradations into rocks which may be called dolomitic slates or impure magnesian limestones. These do not differ markedly, in fresh specimens, from the slates already described, though they usually do not show such perfect cleavage. On weathered surfaces they become yellow, and projecting corners are rounded by solution. They are distinguished from the less calcareous slates by their somewhat readier effervescence with acids. The effervescence is, however, hardly ever brisk, indicating that the rock is for the most part decidedly magnesian; but rarely a specimen is found which effervesces more vigorously and seems to consist mainly of calcite. Examined in thin section under the microscope, all specimens of these rocks are found to contain a considerable proportion of quartz and sericite.

The variegated rocks of the middle part of the formation are connected by all intermediate types, but only the better-characterized ones need by considered.

The sandstone which is the most characteristic rock of the middle division has features that distinguish it from any arenaceous rock of the other formations. On fresh fracture it is light gray, compact, and quartzitic in appearance and generally shows abundant little flakes of white mica lying parallel to the bedding planes. The weathered surfaces are as a rule pure white, though in some of the rock they are delicately tinted with red and yellow. The plane joint surfaces when weathered are slightly rough, but not so harsh to the touch as the weathered sericitic quartzites. Upon these surfaces, when they have been long exposed to the etching action of atmospheric water, a beautiful cross-bedded structure appears, of which no trace is visible upon fresh fractures. The roughness of the weathered surface and the clearness with which the internal structure is brought out by weathering indicate the presence of some easily soluble material in the cement, and the brisk effervescence that takes place on the application of cold dilute acid shows that this material is mainly calcite.

The ocherous specks derived from the weathering of siderite, so conspicuous in some of the quartzitic beds of the lower formations, are notably absent in these calcareous sandstones. Very characteristic, however, is the common occurrence of pyrite in well-formed cubes a few millimeters in diameter.

The limestones of the middle part of the Wallace are usually dark blue-gray in color, though lighter greenish-gray tints are also to be seen. They are dense and very fine grained, and dull in luster. The nature of these rocks is most easily recognized in weathered exposures by their tints of ocher yellow and the rounded surfaces produced by solution. Standing out upon such surfaces there are usually many little irregular knobs of siliceous matter. The application of cold dilute acid produces some effervescence, but the action is seldom vigorous, the chemical behavior thus indicating that the carbonate is partly dolomite and partly calcite.

The study of thin sections reveals the presence of a small proportion of quartz and a little sericite. The coloring matter of the blue-gray variety is a very finely divided dust that is probably carbonaceous.

The blue-gray argillites are partly like ordinary "blue slate," but the finest-grained argillite does not in general form beds more than a few inches thick. It commonly occurs in layers but a fraction of an inch thick interbedded with and grading into calcareous and arenaceous layers. A very common and characteristic rock in this division of the Wallace, especially in its upper part, is a sort of sandy shale, not very different from that which predominates in the Prichard, except that the banding is broader, less regular, and more distinct. An excellent exposure of this phase of the Wallace occurs on the road opposite the mouth of Lake Gulch, where smooth joint surfaces cutting across the bedding display in section the sun cracks that are so generally present in the argillaceous beds of the Wallace. The cracks are in the finer-grained dark layers and are filled in with the slightly coarser whitish sand. At this point the beds dip steeply to the south, but the cracks are on the northern or under side of the clayey layers, showing that the beds are overturned and illustrating a manner in which sun cracks may frequently be used to detect an overturn.

The blue-gray argillite so abundant in the upper beds of the Wallace is not very unlike the rock just described, but is more finely laminated. Some good exposures of this rock occur on the West Fork of Placer Creek and on the north slope of the ridge south of the Placer Creek drainage basin. A certain phase of the upper Wallace is a regularly laminated dark slate very similar to that which constitutes most of the Prichard formation, but to the eye of one familiar with both there are distinct differences between the two, one of the more obvious being that whereas the Prichard slate weathers red the Wallace weathers in drab or yellowish tints.

Dynamic action has produced in the Wallace rocks many beautiful and instructive manifestations. The lower green slates, not being conspicuously banded, do not clearly show the effects of folding, and they seem to be less crumpled than the middle Wallace rocks, but their fine-grained homogeneous character adapts them to the development of slaty cleavage, which occurs in them generally and in many places shows a fairly high degree of perfection and regularity. In the higher beds, where the bedding is conspicuously marked by rapid alternations between rocks differing in color and composition, crumpling of a minute and pronounced character is conspicuous. The most accessible and perhaps the most remarkable examples of this structure are to be seen along the main road up the river for about 2 miles above Wallace (see Pls. V, *B*, and VI) and along the Canyon Creek and Ninemile Creek roads for a mile up from the town. The sun cracks in the crumpled shales show an extreme degree of contortion, and many of them are entirely pinched off, which illustrates the great degree of internal movement that these rocks have undergone. Cleavage is generally developed in the middle Wallace beds, and, as in an exposure a short distance east of Wallace, may be seen at numerous localities in a highly inclined position cutting across the wrinkled beds of shale. The perfection of the cleavage varies much according to the character of the rock, even in the same outcrop, being best developed in the softer, more argillaceous layers and generally not present at all in the hard calcareous quartzites. In the banded rocks composed of argillite and argillaceous sandstone, the cleavage has a zigzag character, changing direction as it passes from a softer to a harder layer, and more nearly coinciding with the bedding in the softer layers.

It is significant that in general the cleavage is better developed in the lower than in the higher beds, and this fact can not be explained entirely on lithologic grounds, for the argillaceous layers of the highest part seem well adapted to the development of cleavage. The thin-bedded argillites of the upper Wallace show, however, in sections across the bedding the most minute and complex folding and faulting, which has evidently thickened the strata to a considerable degree.

*Microscopic features*:—The microscopic characters of the leading types of Wallace rocks are briefly as follows:

The green slates poor in carbonate are seen to consist essentially of a very fine grained mixture of quartz and sericite, in which no distinction can be made between clastic grains and cement. A little chlorite occurs, but is not conspicuous. In many specimens the schistose structure is beautifully shown by the arrangement of the ragged and elongated shreds of sericite in a common direction inclined to the planes of stratification, which causes them to extinguish almost simultaneously when the stage of the microscopic is revolved. In this rock multitudes of very minute prisms of rutile occur, and tourmaline crystals, which, though microscopic, are larger than the individuals of quartz and sericite, are very abundant in some specimens.

The green slate passes by continuous gradations into limestone, which invariably, however, contains a little quartz and sericite. The carbonate occurs partly in irregular grains, but usually for the most part in more or less imperfect rhombohedra which are probably of a magnesian carbonate. The grains of carbonate and of quartz and the flakes of sericite are of the same order of magnitude. Veinlets, usually of lenticular form, and small concretionary bodies occur into whose composition enter calcite and other carbonates, quartz, and a soda-lime feldspar. Pyrite and other metalliferous minerals are in places developed sporadically. Siderite is not distinguishable, usually, from the other carbonates, but in some slides a few grains with especially strong pleochroism which seem to be of that mineral may be seen.

The calcareous sandstone of the middle Wallace, when examined microscopically, is seen to be somewhat arkose in constitution. The grains, though predominantly quartz, include considerable feldspar and muscovite. The cement is abundant and contains quartz and sericite, but consists in greater part of calcite, which constitutes generally about 15 per cent of the rock, or even somewhat more. In much of this rock the carbonate occurs in individuals larger than the quartz grains, which would seem to indicate that it had to some extent replaced the quartz. Stronger evidence to the same effect is given by the inclosure within the quartz of microscopic, sharply crystallized rhombohedra. On the other hand, many of the thin sections give evidence of the secondary enlargement of the quartz grains.

The constituents of subordinate importance, besides the pyrite, which is conspicuous megascopically, are zircon, tourmaline, and magnetite, with the white cloudy material already noted in the description of other rocks.

The bluish argillaceous rocks of the middle and upper parts of the Wallace present no microscopic characters of especial interest, being essentially similar to rocks already described, in the Prichard formation, except that they mostly contain a little carbonate. They are composed essentially of quartz and sericite, commonly mingled with a good deal of chlorite and carbonaceous dust. By addition of carbonates, they grade into impure limestones.

*Distinctive characteristics.*—Of the diagnostic characters of the Wallace formation, the most important and the most useful in distinguishing the formation is the presence in large amount of calcareous and dolomitic beds. Such material is practically absent from all the other formations of the district except the St. Regis, and in that it plays an insignificant rôle. The calcareous rocks when weathered are marked by rounded forms and ocher-yellow colors, so characteristic that they are recognizable even in small fragments, and the abundant presence of such fragments in an unexposed area sufficiently indicates that the underlying rock is Wallace. The means of distinguishing the different parts of the formation have already been pointed out.

Though the discrimination of the Wallace from other formations can generally be effected in the way just described, there are some localities where the lower or green slate portion may be confused with certain phases of the Burke and St. Regis formations. Underground this is especially true, for the lower Wallace when unweathered resembles the typical Burke, the presence of calcareous material being then recognizable only by testing with acids. The St. Regis formation also contains, as has been pointed out already, beds lithologically identical with the lower Wallace. Beds of this character must be assigned to one or the other formation according to their relation to the purple rocks which are characteristic of the St. Regis. The Wallace green slates are indeed more calcareous on the whole than those of the St. Regis. The boundary between the two formations can, however, be fixed more accurately by considering all the purple as St. Regis than on the basis of the greater amount of carbonate in the Wallace rocks. The upper limit, though the transition to the overlying Striped Peak formation is gradual, is pretty definitely fixed by considering the highest calcareous beds as belonging to the Wallace.

### STRIPED PEAK FORMATION.

#### DISTRIBUTION AND EXPOSURES.

The Striped Peak formation, named for a mountain on the divide between Big Creek and Placer Creek, has comparatively small areal development in the Cœur d'Alene district. It occupies a very small area west of Ninemile Creek and forms a discontinuous strip extending from Dobson Pass northward, but neither of these localities affords good exposures. There are, however, two rather extensive areas lying east of the South Fork of Big Creek in which fine outcrops of the formation may be observed. In the larger of these lies Striped Peak, on whose long, barren crest the inclined varicolored strata of the formation crop out and give the striped appearance which suggested the name.

#### THICKNESS.

Along the crest of Striped Peak the beds dip southward at moderate angles, and a short distance to the south they are cut off by a strong fault. The section across this area gives the best estimate available for the thickness of the formation. The exposures are not sufficiently complete to make this estimate precise, but an approximate thickness of 1,000 feet is indicated.

#### LITHOLOGY.

The Striped Peak formation is composed of thin-bedded rocks, including shales and quartzitic sandstones marked with ripple marks and sun cracks and mostly reddish purple and green in color. It is so very similar to the St. Regis formation that the two were for a time confounded with one another, and lengthy description would therefore be, to a large extent, mere repetition. The Striped Peak beds are perhaps less deeply colored, and the prevailing color of the quartzitic beds inclines rather to pink than to a more bluish purple. Of the secondary features resulting from dynamic action, only jointing has been noted in the Striped Peak formation, no distinct cleavage having been observed.

The formation is not likely to be confused with any other in the district except the St. Regis, but from this it can be distinguished only by its stratigraphic relations.

Microscopically as well as megascopically these rocks are essentially similar to those of the St. Regis formation, except that they fail to show distinctly schistose arrangement of the micaceous material.

## IGNEOUS ROCKS.

### PRINCIPAL KINDS AND GENERAL RELATIONS.

The igneous rocks of this district are all intrusive. They are classified, for purposes of mapping and description, as monzonitic rocks, diabase, and lamprophyre.

All these rocks have been found in plainly intrusive relation to each of the Algonkian formations, except that the monzonites have not been seen in contact with the Striped Peak. All, however, were undoubtedly erupted after the vast period of conformable deposition had closed. The order of intrusion is not known, but a decomposed rock similar to the lamprophyre has been found cutting the monzonite, and a lamprophyre dike runs parallel to the Dobson Pass fault, which is later than the monzonite.

The monzonitic rocks are those locally known as "granite." They are granular or holocrystalline-porphyritic, and distinguished from the other igneous rocks by prevailingly light colors. They occur mainly in irregular masses without marked elongation, but also form a few dikes and sheets. They far surpass the diabase and lamprophyre in volume and in area of exposure, and are of economic interest as having been concerned in the deposition of some of the ores.

The diabase and lamprophyre are dark, fine-grained, holocrystalline rocks, which in this district occur only in dikes, mostly of no great size, and inconspicuous because they weather more rapidly than the sedimentary rocks into which they are intruded. The diabase dikes trend from east-west to northwest-southeast and accompany the important fractures with which most of the ore bodies are associated. The lamprophyre dikes, more numerous than those of diabase, trend in various directions from west-northwest to northeast.

## MONZONITIC ROCKS.

### VARIETIES, DISTRIBUTION, AND MODES OF OCCURENCE.

A glance at the geologic map (Pl. II, in pocket) will show that the numerous areas of monzonitic rocks fall into two groups. Most of these, including the largest, lie in a belt that extends from Gem and Bradyville northeastward with decreasing breadth nearly to Bear Gulch. The others form a more irregular group in the drainage basins of Dudley and Twomile creeks.

The rocks here described under one heading, and indicated on the map by one color, comprise several apparently widely differing types. Petrographical study, indeed, shows that they vary not only in texture but in kind. Under the existing conditions of occurrence and exposure, however, the classification adopted seems the only practicable one and is justified by the close consanguinity existing between the several kinds. These, moreover, are found in relations so intricate that they can not be completely deciphered, and are incapable of representation on the map; and gradual transitions, as, for example, from syenite to monzonite, are of common occurrence. It is probable that all these rocks are the result of a single episode of intrusion, and that they were derived from one great body of magma.

The principal types in the group may be described briefly in terms of characters observed readily in the field, preparatory to indicating their distribution and mode of occurrence.

In the large masses, and at some distance from contacts, the prevailing rock, fairly uniform over large areas, is a coarse-grained, light-gray, usually somewhat porphyritic monzonite. The main bulk of this rock consists of feldspar of two species—striated lime-soda feldspar and unstriated alkali feldspar. Other constituents visible to the naked eye are a little quartz and small amounts of the dark minerals hornblende, pyroxene, and biotite. A part of the alkali feldspar forms conspicuously large crystals or phenocrysts with a diameter of about one-half inch, which, scattered through a mass of smaller grains, give the rock its porphyritic appearance. This, which may be designated the normal local type of the monzonite, forms the greater part of the three largest areas and portions of the smaller ones. The aggregate extent of its outcrops, of which the best are to be found in the basin of Ninemile Creek, is very considerable, yet, owing to the large amount of weathering it has undergone and to the absence of artificial cuttings in it, this most abundant type is the most difficult of all to gather in sufficiently fresh condition for satisfactory petrographic study.

In the smaller irregular masses, where cooling has been more rapid, the magma has crystallized in large part as a monzonite porphyry. This rock differs from the porphyritic monzonite into which it grades in being of finer texture, and shows feldspar phenocrysts with an average diameter of less than one-fourth inch thickly set in a groundmass so fine grained that its constituents can not be discriminated with the naked eye. The dark minerals are clearly less abundant than in the granular monzonite. This rock forms portions of the masses in the Twomile and Dudley basins, and the greater part of the small areas east of Raven on Prichard Creek. It is in these latter areas that the best exposures and freshest material of this type are found.

Somewhat different is the rock forming the dikes and sheets. This is darker, greenish in color, and generally much decomposed. The prominent phenocrysts are of feldspar, but the dark constituents are more abundant than in the porphyry just described.

The members of the group most peculiar in character and most remarkable in appearance are certain porphyritic syenites. Their most striking feature is the abundant development of unstriated feldspar in oblong crystals some of which attain a length of over 2 inches and which lie, with somewhat parallel arrangement, in a rather dark granular groundmass that varies in character and amount. These syenites are conspicuously displayed on the Canyon Creek road at the lower end of Gem, and on the north side of the East Fork of Ninemile Creek, near its junction with the main stream, where the cutting for the railroad affords the best opportunity to study their occurrence and to obtain material for laboratory investigation. The relations of the several varieties of syenite to each other and to the monzonite are complex and can not be made out in an entirely satisfactory manner. Syenite with a groundmass very rich in dark minerals was seen to grade into syenite with a less basic groundmass. At another point a rather dark porphyritic syenite forms streaks in a syenite consisting almost entirely of feldspar, but these apparently intrusive bands are ill defined, as if the intrusion had taken place when the invaded rock was still in a pasty condition. Monzonite, fine grained and nonporphyritic, was in one place found in the form of a small dike cutting porphyritic syenite, and a knob of monzonite closely skirted by the road just below Gem is in a position that suggests an intrusive relation to the porphyritic syenite on both sides. The conclusion drawn from these observations is that the porphyritic syenite formed as a somewhat heterogeneous marginal segregation along the southern edge of the principal plutonic mass, and that it was broken up and intruded by the monzonite, perhaps before being completely solidified.

Cutting the granular rocks in dikes that are not very large or numerous are aplites, pegmatites, and lamprophyres, the last very much decomposed.

## PETROGRAPHY.

### MONZONITE.

After this brief sketch of what may be seen in the field, it remains to give a more detailed account of the mineralogical and textural features of these monzonites and related rocks.

Of the coarse porphyritic monzonite the best specimen, which, however, was much decomposed, was obtained from the Alameda tunnel. It shows phenocrysts of pink unstriated feldspar scattered in a medium-grained granular groundmass. The microscopic section contains none of the phenocrysts, but shows the groundmass to consist of cloudy plagioclase, a distinctly smaller amount of perthitic microcline and orthoclase, considerable quartz, and some deep-green hornblende, while biotite is represented by pseudomorphs of chlorite, and pyroxene by masses of pale-green amphibole and epidote. Apatite and titanite, as accessories, are comparatively abundant. The extensive alteration of the rock has given rise to much epidote and pyrite, considerable chlorite and kaolin, and a little calcite. It is noteworthy that though the biotite, pyroxene, and plagioclase are much decomposed the alkali feldspar and hornblende are comparatively fresh.

Apparently very similar in composition to this rock, but not porphyritic, is a monzonite collected at the roadside just below Gem. It is a medium-grained granular rock, of which the constituents megascopically recognizable are feldspar, hornblende, and a little quartz. Of the feldspar, striated plagioclase, opaque and white, in rather small idiomorphic crystals, can be distinguished from the somewhat larger grayish and more transparent, imperfectly formed crystals of alkali feldspar. The two are present in nearly equal amount.

The microscope shows, in addition to the constituents named, a little biotite, some small prisms of light-green monoclinic pyroxene, with titanite and magnetite as abundant accessories and apatite as a minor one. The plagioclase is zoned, and parts of the crystals, presumably the more basic parts, are thoroughly decomposed. The clear remnants give extinction angles appropriate to oligoclase and to andesine that approaches labradorite. The alkali feldspar is of later crystallization than the plagioclase and ferromagnesian minerals, and occurs partly in anhedra, while many of the individuals showing rough crystallographic outlines are penetrated by crystals of the earlier minerals. It mostly shows microcline twinning, and is all perthitic. Certain crystals show a striking and beautiful zonary banding, due perhaps to oscillation in the proportion of soda to potash in successive shells, and accentuated in at least one crystal by the interposition of very narrow zones of plagioclase.

Decomposition, though not advanced, has given rise to considerable chlorite, epidote, kaolin, sericite, etc., derived from the pyroxene, biotite, and plagioclase.

The rock has been analyzed in the chemical laboratory of the Geological Survey by Mr. George Steiger, with the following result:

*Analysis of quartz monzonite near Gem.*

| | | | |
|---|---|---|---|
| $SiO_2$ | 61.41 | $ZrO_2$ | None. |
| $Al_2O_3$ | 17.99 | $CO_2$ | None. |
| $Fe_2O_3$ | 2.93 | $P_2O_5$ | .19 |
| FeO | 1.39 | $SO_3$ | .05 |
| MgO | 1.20 | NiO | None. |
| CaO | 4.75 | MnO | .16 |
| $Na_2O$ | 4.01 | BaO | .11 |
| $K_2O$ | 4.59 | SrO | .14 |
| $H_2O-$ | .11 | | |
| $H_2O+$ | .68 | | 100.24 |
| $TiO_2$ | .53 | | |

According to the quantitative classification[a] this rock falls in the sodipotassic subrang of the domalkalic rang of the perfelic order of persalane. This subrang has been named pulaskose. As the norm shows a strong preponderance of the anorthite and albite molecules over those of orthoclase, it is evident that the approximate equality of plagioclase and alkali feldspar in the mode is due to the fact that the perthitic microcline and orthoclase contain a large amount of soda.

From the type of monzonite just described there is variation on the one side toward syenite, by increase in the proportion of alkali feldspar, and on the other toward diorite, by increase in the proportion of plagioclase. A specimen obtained near the contact with the sedimentary rocks on Sunset Peak shows a preponderance of plagioclase over orthoclase, with moderately abundant hornblende and no pyroxene. It might properly enough be classed as a granodiorite. On the other hand, much of the material seen in the field seems to show a rather large amount of porphyritic alkali feldspar, and some of it may be considered as belonging to syenite. A strong preponderance of alkali feldspar, however, is not found except in the narrow zone along the southern border of the main area.

### MONZONITE PORPHYRY.

The typical monzonite porphyry, as exemplified by specimens from the areas east of Raven, shows phenocrysts of feldspar equaling or exceeding in volume the nearly aphanitic groundmass. The larger phenocrysts are of pinkish or grayish alkali feldspar, while white plagioclase forms phenocrysts that are smaller but rather more numerous.

Microscopically the groundmass is found to consist essentially of two feldspars and considerable quartz. As scarce accessories occur magnetite, apatite, and titanite, and in some specimens a very little biotite or hornblende is found. The plagioclase is remarkable for its extremely fine lamination. Its extinction angles indicate oligoclase and andesine-oligoclase. The alkali feldspar is orthoclase, perthitically intergrown with an unusually large proportion of plagioclase, which forms not only the familiar veinlets, but nuclear masses and inclusions, commonly in the same optical orientation as the veinlets of the same crystal. In many of these intergrowths the plagioclase equals the orthoclase in quantity, or even exceeds it, and many of the phenocrysts that are made up chiefly of plagioclase have borders of perthite.

Although the perthite seems slightly to exceed the plagioclase, it shows no decided predominance, especially when we deduct the intergrown plagioclase. The two feldspars are so nearly equal in amount that the rock may properly be classified as a monzonite porphyry. Comparison of its mineralogical composition with that of the granular monzonite described above will make it evident that this rock is decidedly less basic.

The composition of the rock forming the dikes and sheets inclines more toward that of diorite. Most specimens collected are too much altered to be satisfactory material for study, but comparatively fresh rock was taken from a small dike at the head of Granite Gulch. This is a

[a] Cross, Iddings, Pirsson, and Washington, Quantitative classification of igneous rocks, 1903.

porphyry of rather dark gray color. Its phenocrysts are mostly of plagioclase, but there are some of perthite, and both feldspars reappear in the groundmass, where the perthite equals or exceeds the plagioclase. The groundmass contains a large amount of quartz and considerable brown biotite The accessories are magnetite, apatite, zircon, and titanite. Decomposition has given rise to considerable calcite, sericite, chlorite, epidote, clinozoisite, and pyrite.

### PORPHYRITIC SYENITE.

Of the syenite exposed near Gem and Bradyville, the most abundant constituent is unstriated feldspar, forming phenocrysts most of which are between three-eighths of an inch and 1 inch long, but some of which are as much as 2 inches. These lie in a medium-grained groundmass whose megascopically visible constituents are feldspar, greenish-black hornblende, lighter-green pyroxene, and usually titanite. The amount of the groundmass and its richness in ferromagnesian minerals vary between rather wide limits, and the groundmass is most femic where it is most abundant. Some specimens have feldspar phenocrysts embedded not very thickly in a dark-green mass seemingly composed almost entirely of hornblende and pyroxene; in perhaps the majority of specimens the phenocrysts and groundmass are about equal in volume, but these pass into types where the porphyritic feldspars are crowded together, with the groundmass occupying only small polyhedral spaces between. Where the elongated tabular phenocrysts are close together and have a roughly parallel arrangement, the texture simulates on a large scale that of the typical trachytic groundmass. In some of the most acidic specimens, the texture is no longer truly porphyritic. In other phases of the syenite the hornblende forms phenocrysts.

As the qualitative mineralogical composition of all these rocks is practically identical, the general microscopic characters of the constituent minerals may be indicated once for all.

The alkali feldspar belongs to the varieties orthoclase, microcline, and anorthoclase. The first two varieties are always intergrown with more or less plagioclase, which in some crystals almost equals in quantity the orthoclase itself. Its proportion is greatest in the most acidic rock. The anorthoclase, which is found in but few specimens, is identified by its faint and irregular crosshatching and its small optic-axial angle. The phenocrysts, which are of orthoclase or microcline, have rather numerous inclusions of the other minerals, and all three varieties form more or less irregular poikilitic areas in the groundmass.

Plagioclase, always subordinate to the alkali feldspar, forms separate individuals, small and tending to idiomorphism, that are recognizable in most specimens. Its satisfactory determination is hindered by the great extent to which it has been decomposed. The portions that remain transparent show low extinction angles, but the thoroughly clouded portions were presumably more basic.

Of the ferromagnesian minerals, hornblende is on the whole the most abundant, although pyroxene, in smaller crystals, does not fall far below it in quantity. Biotite is scarce and does not occur in all specimens. The hornblende and biotite belong to the commonest species, but the pyroxene is of less familiar appearance. Its color is green, varying from a rather pale tint to the deep grass color which, in conjuction with the large extinction angle, distinguishes ægirine-augite, and some crystals have a light-green core surrounded by a deep-green periphery. Hornblende and pyroxene are commonly intergrown.

The accessory minerals present in all specimens are magnetite, apatite, and titanite. Some of the more basic rock contains a yellowish-brown mineral of high refractive index, but almost isotropic, which is apparently the lime-iron garnet, melanite.

Most specimens show a good deal of alteration, which affects the various minerals in very different degrees. The alkali feldspar is almost perfectly fresh, and the more acidic part of the plagioclase also, but some of the feldspar crystals, especially in their centers, are clouded with kaolin, sericite, and epidote. Of the ferromagnesian minerals, hornblende has generally almost escaped alteration. Biotite shows much of the usual decomposition to chlorite and epidote. The pyroxene is altering in most specimens, the chief product being a pale fibrous amphibole quite distinct in character from the original hornblende. This uralite is generally associated with epidote, and in places with a mineral like iddingsite. An unusually high degree of alteration is exhibited in some specimens obtained near the mines, where pyrite, replacing chiefly the ferromagnesian minerals, is abundant.

A chemical analysis was made of a specimen taken from the railroad a little east of Bradyville, which will illustrate approximately the petrographic and chemical character of the average porphyritic syenite. Megascopically this rock shows phenocrysts of unstriated feldspar from one-half inch to 1 inch long, about equal in bulk to the medium-grained groundmass of feldspar, hornblende, and pyroxene. The feldspar phenocrysts and the hornblende have a distinctly parallel arrangement. The thin section under the microscope shows that the phenocrysts are of perthitic microline and the groundmass of plagioclase, hornblende, and pale-green augite in small crystals, with larger, elongated, somewhat poikilitic areas of perthitic microcline with which in many specimens plagioclase in rather large patches is intergrown. The plagioclase, finely striated and somewhat clouded, is partly determined as oligoclase. The accessories present are apatite, magnetite, and titanite, all rather abundant. Decomposition has not appreciably affected the microcline or the hornblende. The plagioclase contains numerous secondary inclusions of epidote, sericite, and a fibrous mineral that appears to be an amphibole. The pyroxene is largely replaced, and some crystals completely, by epidote and splintery pale-green amphibole.

The chemical analysis, by Mr. George Steiger, gives the following result:

*Analysis of porphyritic syenite near Bradyville.*

| | | | |
|---|---|---|---|
| $SiO_2$ | 58.53 | $ZrO_2$ | None. |
| $Al_2O_3$ | 16.85 | $CO_2$ | None. |
| $Fe_2O_3$ | 3.49 | $P_2O_5$ | .24 |
| FeO | 2.37 | $SO_3$ | .04 |
| MgO | 1.46 | NiO | None. |
| CaO | 3.93 | MnO | .19 |
| $Na_2O$ | 4.05 | BaO | .10 |
| $K_2O$ | 7.12 | SrO | .14 |
| $H_2O-$ | .12 | | |
| $H_2O+$ | .49 | | 99.83 |
| $TiO_2$ | .71 | | |

According to the quantitative classification, this rock belongs to monzonose, the sodipotassic subrang of the domalkalic rang of the perfelic order of dosalane. It is, however, near the border between the domalkalic and peralkalic rangs, and a relatively small increase of the alkali percentage would throw it into the subrang ilmenose. It is evident that the larger part of the albite molecules enter into the composition of the perthitic alkali feldspar; if most of them went to the formation of plagioclase crystals, the rock would have a monzonitic habit.

## CONTACT METAMORPHISM.

### GENERAL CHARACTER.

The Cœur d'Alene district is not a favorable area for detailed study of contact metamorphism, inasmuch as complexity of structure and poverty of exposure make it impossible to trace for considerable distances the progressive changes shown by a given bed as an igneous contact is approached along the strike. It is impossible, therefore, to do more than illustrate the effect of the magma on the sediments in a somewhat general way.

The contact alteration is most conspicuously manifested by a sparkling crystalline appearance not ordinarily seen in the less altered sediments. The metamorphic rocks are coarser in grain than the unaltered rocks, but even near the contact, where they are coarsest, their elements are rarely more than 2 or 3 millimeters in maximum diameter. No schistose structure, properly so called, seems to have been induced by the intrusion. Cleavage is shown, indeed, by much of the rock in the contact zone, but it seems to be the cleavage due to pressure which is generally present in the rocks of the district. Near the contact there is, indeed, a tendency for the cleavage to become obliterated, and although here the rocks are commonly banded the banding is apparently that of sedimentation. At some distance from the contact, recrystallization and the formation of new minerals have taken place to a noticeable extent without at all obscuring the clastic textures. A few instances have been observed of exceptionally intense action where the materials of the sediments and magma have been commingled.

The rocks of the metamorphic aureole of the monzonite are divisible into two groups according to origin. It has already been shown that the argillites of the Prichard formation, the sericitic quartzites and indurated siliceous shales of the Burke and St. Regis, and the pure quartzites of the Revett constitute a graded series. A graded series is likewise constituted by their metamorphic derivatives, which are rocks composed predominantly of quartz and micas, but locally containing andalusite, garnet, and chlorite. Quite in contrast with these are the rocks produced by the alteration of the dolomitic sediments of the Wallace formation. These are characterized by the presence of pyroxene, which may or may not be accompanied by amphibole and biotite.

The only formations of noncalcareous rocks in eruptive contact with the monzonites are the Prichard and the Burke. Their metamorphism can best be observed on the borders of the largest monzonite area, in the basin of Ninemile Creek and along Canyon Creek near Gem.

### NONCALCAREOUS ROCKS.

The metamorphic rocks of the argillite-quartzite series are colored in tints of gray that vary from nearly black to nearly white. Megascopically their most noticeable constituent is mica in abundant glittering particles, but the large porportion of quartz is recognizable in specimens that are not too fine grained. Pyrite is commonly visible, and in some phases small red garnets appear. Andalusite forms prismatic knots a few millimeters long in a black metamorphosed slate, derived from the Prichard, seen near the monzonite contact on the Dobson Pass road, but although present in many other localities this mineral is not elsewhere conspicuous megascopically because of its occurrence in small irregular individuals without crystal form. Where it is abundant, however, it gives the rock a pinkish tinge.

The best locality for observing the gradual change in the character of the noncalcareous sediments as the contact is approached is on the Canyon Creek road below Gem, south of the point where it crosses the boundary of the main intrusion. About 300 yards southwest of the contact the sheen of mica appears in the slates and impure quartzites and some of the more siliceous rocks exhibit a dappled appearance, due to small round segregations of biotite. The final stage of the alteration is illustrated by pieces from a prospect tunnel that cuts the contact beside the road a little below Gem. The metamorphic rock here is very rich in mica and of a granular texture not unlike that of a fine grained granitic rock.

Microscopic study shows that most of the rocks under consideration are composed chiefly of quartz, muscovite, and biotite. The two micas vary in total amount and in relative porportion to one another; the muscovite is on the whole the more abundant, but only rarely is biotite entirely lacking. Andalusite is developed in some of the more aluminous beds in close proximity to the contact. Garnet is not a common or abundant constituent. It has been found in certain specimens from Ninemile Creek, generally in localities of very intense metamorphism, but it is also found above the abandoned Custer mine on the west side of Custer Peak, and near the summit of the peak itself. These occurrences are rather remarkable in that they are at considerable distance from any outcrops of the intrusive rock, but they seem to be associated with a fissure which may have been an avenue for mineralizing vapors from the magma. In these occurrences the garnet is associated with a green mica and with chlorite. Other minerals which the rocks of this group contain in small amounts are feldspar, pyrite, magnetite, zircon, rutile, tourmaline, apatite, and sillimanite.

Few of the minerals have any peculiarities worthy of remark. The feldspars are acidic plagioclase and orthoclase. The biotite is usually deep brown, rarely green. Much of the light-colored mica is seen to have a small optic-axial angle that suggests phlogopite, although the brownish tint commonly shown by that mineral is not apparent. The tourmaline, which is generally of a brown color closely resembling that of the biotite, forms stouter individuals than commonly occur in the rocks not altered by the monzonite, but does not noticeably increase in abundance with approach to the contact. The sillimanite occurs in the usual hairlike prisms forming roughly parallel groups, inclosed in quartz and the white mica. The reddish-brown grains of garnet are generally not very regular in form, and some contain inclusions of quartz. The andalusite individuals are partly colorless, but a portion of nearly every one, indefinite in outline and lying in a central position, is pale red and pleochroic in thin section.

It is possible to trace all gradations in texture from that of the rocks unmodified by contact metamorphism to that of a typical hornfels, which retains no trace of clastic texture. The first stage in the alteration is signalized by the production of mica in individuals larger than those of sericite so abundant in all the old sediments of the region. In the final stage all the material is completely recrystallized. The quartz, and the feldspar where present, form irregular individuals much larger than the original clastic grains. The micas are also rather irregular in outline and rich in inclusions. Andalusite forms well-developed crystals, free from interpositions, only in the one occurrence already noted, where it is megascopically conspicuous. Elsewhere it shows at most only a rude semblance of prismatic form and contains inclusions in many localities so abundant that their volume exceeds that of the host.

### CALCAREOUS ROCKS.

Metamorphism of the Wallace rocks is best shown along the canyon of Dudley Creek below its forks. The alteration here is surprisingly extensive, considering the small size of the nearest considerable area of monzonite porphyry, and it is highly probable that the roof of a much larger mass is not far beneath the surface.

The metamorphic rocks of this vicinity are fine grained, with no minerals clearly recognizable by the unaided eye except in some a bright-green amphibole. In part they are greenish gray, dappled with ill-defined round whitish spots a few millimeters in diameter that are sections of imperfect spherulitic bodies; in part beautifully banded, with greenish-gray layers 1 or 2 centimeters thick alternating with very fine cherty purplish-brown layers and locally, in addition, bright-green layers rich in needle-like crystals of hornblende.

The identification of the small area of intensely metamorphosed Wallace on the East Fork of Ninemile Creek, remote though it is from any unaltered material of this formation, is based on the close petrographic similarity of the material composing it to the metamorphics of Dudley Creek, whose origin is clear. The Ninemile area shows the same dappled greenish-gray rock and green and brown banded material that are found on Dudley Creek, but exhibits some phases that indicate more intense metamorphism. Some of these last contain rather numerous megascopic crystals of hornblende; other specimens contain, in addition, large irregular poikilitic crystals of feldspar and are undoubtedly a product of the commingling of the monzonite magma with the sedimentary material reduced to a liquid form by its heat.

Microscopically examined, all these metamorphic rocks are found to contain quartz and colorless diopside as chief constituents. Deep-green hornblende is present in most specimens; its amount varies greatly, but is generally less than that of the pyroxene. Muscovite is rather plentiful in many specimens, but rare or absent in others. Biotite, generally greenish brown, but rarely green, is more commonly present than not, but it also is very variable in amount. The most characteristic accessory is titanite, which in all the specimens examined forms numerous very small yellowish grains and crystals. Small quantities of magnetite, apatite, and zircon are present in various slides. In two a little carbonate and zoisite were found. Tourmaline, rather unexpectedly, was not detected.

Pyroxene associated with quartz is found to constitute a large proportion of the greenish-gray layers, being almost colorless even in mass. It forms rather small grains and blunt, imperfect prisms, which generally contain abundant inclusions of quartz. The light spots seen in the dappled facies are spherulitic masses of pyroxene, which does not show regular radial arrangement. The biotite, which occurs in purely microscopic particles, gives color to the brownish cherty layers, of which the larger portion is quartz. The hornblende forms more slender individuals than the pyroxene and has better crystal form, the prism faces being commonly well developed. Like the pyroxene, it habitually incloses grains of quartz. The crystals that are prominent in certain of the Ninemile Creek specimens are remarkable for the perfection of their crystallographic development and also for their poikilitic texture, being crowded with innumerable microscopic grains of quartz.

The feldspar-bearing rock deserves especial description. Megascopically it shows contorted bands—some of which are dark grayish green, the others coarse grained and rich in feldspar—and a small, ill-defined veinlet of aplite. The large individuals of feldspar exhibit rather dull cleavage reflections broken by inclusions of hornblende.

A thin section of the coarser part is made up of several large interlocking plates of microcline crowded with minute grains of quartz. The hornblende, partly bounded by crystal planes, is similarly rich in quartz inclusions. In scattered clusters occur abundant minute particles of biotite. Titanite forms numerous small crystals, and there are some very diminutive crystals of garnet. Another section, apparently from the finer-grained portion of the rock, is very heterogeneous. A part of it is a mosaic of quartz grains; a part shows poikilitic alkali feldspar and well-formed hornblendes. Locally developed is considerable pyroxene in small grains. There is abundant titanite and some apatite and zircon.

## DIABASE.

### OCCURRENCE AND DISTRIBUTION.

The diabase of this district is a dark greenish- to brownish-gray rock, fine to medium grained, consisting chiefly of feldspar laths embedded in black pyroxene that shows no crystal form. The diabase dikes are intimately and doubtless genetically associated with the great system of faults that traverse the district in an east-west to northwest-southeast direction. Many of the dikes occupy the fissures of the great faults, but others fill subsidiary fissures parallel to them.

The majority of these intrusive masses are small, and inconspicuous because they readily decompose and do not stand up above the adjacent sedimentary rocks. Many which are found in mine tunnels are concealed at the surface by waste. A few, however, are distinguished by greater prominence and size. One example is that of a short, thick dike on the north side of Prichard Creek, about a mile and a half above Raven, which gives rise to a large talus at the side of the road. But by far the largest of the diabase dikes in this district is the one indicated on the map as lying at the southern limit of the district, south of Placer Creek. Within the area mapped its size is moderate, but about a mile southeast of the boundary it attains a width of 1,000 feet and forms a rounded knob. It is said to extend 20 or 30 miles farther east, maintaining its large size and conspicuous topographic expression. It is noteworthy that this dike is in line with an important fault fissure, which was traced for 12 miles to the western limit of the district.

### PETROGRAPHY.

The diabase, best exemplified by specimens from the great dike just described, has the familiar ophitic texture. Laths of plagioclase, generally white and semiopaque from decomposition, are embedded in a dark mass consisting chiefly of pyroxene, but comprising some rather large grains of iron ore.

Examined in thin section the rock is found to be a siliceous type of diabase, for it is free from olivine and contains quartz. The principal constituent is plagioclase, which, in the few individuals not too decomposed for determination, appears slightly zoned, the crystals being mainly labradorite, with somewhat more sodic outer shells. The second in importance is augite, of a pale-brownish color with occasionally a faint tinge of violet. In cross sections the prismatic cleavage is distinct and there are in places a few cracks parallel to the orthopinacoid, but the cleavage in this direction is nowhere prominent. A peculiar feature generally present is a cleavage parallel to the base, which seems to be quite unconnected with any lamellar twinning. Simple twins parallel to the orthopinacoid are common. The iron ore shows invariably the skeleton forms characteristic of ilmenite. The quartz fills interstices between the other minerals and is in many places intergrown with a cloudy feldspar that shows no twinning and is undoubtedly orthoclase. Apatite is comparatively abundant in long, slender needles that penetrate all the other minerals. Besides these primary minerals universally present there is in some specimens a very little biotite and apparently primary hornblende.

The minerals have crystallized from the magma in the order usual for this class of rocks. The plagioclase is idiomorphic against all other constituents but apatite. The augite, though much of it enwraps the plagioclase, does not form broad ophitic plates. It is in some places sharply idiomorphic against the ilmenite, though elsewhere this relation is apparently reversed. The quartz and orthoclase have crystallized last and practically at the same time.

None of the diabase is fresh. The plagioclases are in greater part replaced, chiefly by colorless mica and zoisite, though scapolite also occurs in some specimens. The augite is more or less uralitized and also gives rise to some material resembling iddingsite. From the green splintery uralite the supposedly original hornblende is distinguished by color and form, being deep greenish brown and in part well crystallized. Chlorite is formed at the expense of biotite, and the ilmenite is to some extent replaced by leucoxene.

## LAMPROPHYRE.

### OCCURRENCE AND DISTRIBUTION.

Certain dikes whose materials show some differences in composition, but have several essential characters in common, have been mapped in one color and will be described here together. They are dark-colored, rather fine grained rocks, whose chief constituents are plagioclase, biotite, and hornblende. The most striking and diagnostic feature visible megascopically is the presence of abundant well-formed slender prisms of hornblende and tablets of biotite, which distinguish the lamprophyre from the diabase.

These dikes occur chiefly north and east of Kellogg and east of Murray, but isolated ones are seen near Burke, near the Morning mine, and near Dobson Pass. One of them is cut by the Grouse tunnel in Grouse Gulch, but was not found at the surface. Their direction ranges from about northwest to about northeast. Their width is rarely more than 10 yards.

The lamprophyre shows even more decomposition than the diabase and does not form conspicuous topographic features. Some of the best exposures are in a railroad cut just east of the mouth of Elk Creek, and along the steep rocky slope north of the South Fork of Cœur d'Alene River and east of Kellogg, and on the road a mile north-northwest of Dobson Pass.

### PETROGRAPHY.

The lamprophyres of the Cœur d'Alene district are dark gray, holocrystalline, and of fine to medium fine grain. They show a good deal of variation in megascopic appearance. The most common type is an even-grained rock which shows abundant crystals of hornblende, whose characteristically slender prismatic form makes them very noticeable; biotite forms numerous small foils; and feldspar, usually of an opaque white, is recognizable. In many specimens the ferromagnesian minerals show a tendency to porphyritic development, which is strongest in the biotite; and in these specimens the groundmass becomes very dark and almost aphanitic, although small crystals of hornblende and biotite can still be detected. A most striking illustration of this facies is seen in the dike exposed just east of Elk Creek. The rock composing this dike contains, in an almost aphanitic groundmass, great numbers of shining brownish-black hexagonal tablets of biotite, some of which reach three-eighths of an inch in diameter. A rock in strong contrast to this in megascopic appearance, more because of different texture than because of widely different composition, forms a small intrusion north of the South Fork of Cœur d'Alene River and east of Kellogg. It is coarser grained and somewhat richer in feldspar than the material of the other lamprophyre dikes and of a not very dark greenish-gray color. White and pink feldspar, decomposed biotite, hornblende, and some dull-green material are distinguishable by the unaided eye. The hornblende does not form such conspicuous elongated crystals as usual, and few of the biotite foils are more than 2 millimeters in diameter.

Microscopically the essential constituents of these rocks are seen to be plagioclase, biotite, and hornblende, with augite in some specimens, and a rather small amount of orthoclase and quartz. The plagioclase is the most abundant constituent, and the hornblende is generally second in abundance; the biotite, whose amount varies a good deal, occupies in some specimens the second place, but is generally subordinate to the hornblende. As accessories, magnetite and apatite occur in all specimens, while titanite and zircon are detected only in a part. Secondary material is generally plentiful. The texture, except for the local porphyritic development of the ferromagnesian constitutents, is typically panidiomorphic. Plagioclase, biotite, hornblende, and augite show in general fairly good crystal form, somewhat marred by mutual interference. Room for growth has been given by the presence of a little residuum of acidic material which, remaining liquid until the moment of final solidification, has crystallized as quartz and orthoclase, and these minerals, commonly intergrown as micropegmatite, fill interstitial spaces.

The plagioclase crystals have cores much more basic than the peripheries, but in polarized light the one appears to shade into the other and there are no distinct zones. The species composing them range from labradorite to acid oligoclase. Rather characteristic is the scarcity of albite striæ, many individuals being only simple twins. The biotite is of a deep-brown color. The hornblende is mainly brown, but exhibits olive and grass-green tints in some specimens. Many crystals have brown centers and green peripheries. The augite in thin section appears faintly tinged with green or almost colorless. Slender needles of apatite are generally abundant.

The alteration of these rocks is generally even greater than would be expected from their megascopic appearance. Their common secondary constituents are calcite, epidote, chlorite, kaolin, and talc. The more basic part of the plagioclase is generally clouded. The biotite is more or less affected by the common alteration to chlorite and epidote, but in some specimens it has a remarkable degree of freshness. The porphyritic crystals from the dike east of Elk Creek are almost perfectly fresh, though the remainder of the rock is extremely decomposed. The hornblende is resistant, but the augite less so, and in some specimens it seems, though absent, to be represented by pseudomorphs of chlorite or serpentine. In at least one dike, near the mouth of Spring Gulch, olivine seems to have been present originally. This rock contains hornblende, biotite, and augite—the last considerably altered to calcite and serpentine. Several areas larger than those formed by the other crystals are composed of talc. They have slightly elongated form, are generally irregular in outline, though one or two give some suggestion of the familiar double-pointed prism of olivine, and they contain no particle of any original mineral.

## TERTIARY AND QUATERNARY DEPOSITS.

### CLASSIFICATION, ORIGIN, AND GENERAL MODES OF OCCURRENCE.

The only rocks in the Cœur d'Alene district which are younger than the pre-Cambrian sediments and igneous intrusives already described are those included in the third principal group mentioned in the introduction to this chapter. They consist of deposits of gravel, sand, and silt, laid down upon the profoundly eroded surfaces of the older rocks by streams of water and by glaciers. They are accumulations of small area and volume as compared with the older rocks, and they have not been so thoroughly studied nor so completely mapped as the formations previously described, for two reasons. On the one hand they are of less economic importance, and on the other they are in most places poorly exposed. Owing to the tendency of unconsolidated materials to creep down hill, it is generally difficult to determine to what extent they are in place and to locate their boundaries with precision. Many of the smaller areas of gravel upon the valley sides, as well as the narrow strips of valley alluvium along the minor streams, too small for cultivation and of no importance as placers, have accordingly been neglected in the mapping.

For purposes of mapping and description the deposits under consideration are classified, on the basis of origin and mode of occurrence, as (1) terrace gravels, (2) glacial deposits, and (3) valley alluvium. The order in which they are here mentioned is in general that of age, although the period in which the terrace gravels were deposited may have been overlapped to a slight extent by that in which the later deposits were formed.

The terrace gravels (see Pl. VI, *B*, p. 34) occur upon benches or flat-topped spurs at various levels up to more than 1,000 feet above the present valley bottoms. In their present state they are but mutilated remnants of sheets that were at one time far more extensive and continuous. The character of these deposits of thoroughly waterworn materials and their elevated position make it clear that they are the work of streams in past stages of topographic development. Meandering in their valleys these streams deposited their loads of sediment upon their floors, especially in times of flood; but from time to time uplift or other causes brought about conditions favorable for rapid down-cutting, and remnants of the old flood plains were left on the valley sides.

The uncertainty in the matter of age indicated in the heading of this division pertains chiefly to the terrace gravels. It is known that the highest and oldest of these are Tertiary. Not only is it inherently improbable that the immense volume of rock removed in sinking the valleys for a thousand feet or more could have been excavated in Pleistocene time, but there is clear evidence that within 25 miles of the western boundary of the district the valleys had nearly attained their present depth even in the early Miocene. About the shores of Lake Cœur d'Alene and up the valley of Cœur d'Alene River as far as Medimont there are patches of basalt in positions which prove them to be remnants of the great basalt flows poured out over the Columbia Plain. As these basalts have been shown by evidence gathered in other regions to be Miocene, it is certain that the major valleys of the region were deeply incised in mid-Tertiary time. It is not improbable, on the other hand, that some of the later and lower terraces are Pleistocene. But in the present state of knowledge it is impossible to classify satisfactorily the terraces of the district on the basis of age. An attempt is made, however, to correlate some of the more voluminous of these deposits with the basaltic eruptions on grounds indicated in the chapter on geologic history (pp. 70–77).

The former existence of alpine glaciers in this region has already been mentioned. They have left a conspicuous topographic record in the cirques and U-shaped valleys which lie among the higher peaks and ridges. The second of the three classes of unconsolidated deposits above mentioned consists of accumulations of fragments torn by the glaciers from the mountain masses, chiefly in the upper parts of the areas formerly occupied by perpetual ice. The distribution of such material affords the best available means of learning how far the vanished glaciers of the district were able to creep down the valleys into successively warmer layers of air before the loss from melting overbalanced the accession of material from the colder zones above, and to what depth they filled the canyons. The information which they afford may be supplemented by observations of rock ledges rounded and scratched by débris held by the moving ice.

Although the glacial deposits, technically known as moraines, are not subdivided in the mapping, they are susceptible of classification, according to mode of deposition, as lateral moraines and terminal moraines. The former accumulate at the sides of ice rivers and have the character of linear trains of bowlders and other débris or of terraces which are narrower and less even topped than those formed by streams, from which they are also distinguished by the character of the material composing them. The terminal moraines consist of the material which is carried on and in the glacier to its end, where it is deprived of its support by the melting of the ice. The material mapped is mainly of the latter class. If a glacier remains nearly stationary for some time, then retreats rapidly, it leaves a rudely crescent-shaped mass of débris whose concavity faces up the valley. If, however, the ice recedes more slowly without halting long at any one point, it leaves an irregular sheet of débris along the part of the valley through which it has thus receded. In the Cœur d'Alene district the recession of the ice appears to have occurred in general according to the manner last indicated, and few well-defined terminal moraines are to be found except at those places in the high cirques where the ice front made a last stand before the final disappearance of the glaciers.

The alluvium that forms the present floors of the valleys is for the most part of geologically recent age. It has been deposited by means which may be seen in operation to-day, and which have already been indicated in discussing the terrace gravels. Two causes of abnormally rapid deposition of stream gravels existing at two periods of Quaternary time may, however, be mentioned. First, the period in which the ice was retreating must have been characterized by swollen streams heavily laden with glacial detritus, and the large quantity of gravel which now lies in the valleys of certain shallow brooks gives evidence that such conditions must have prevailed in some former period. Second, the mining industry has locally caused a disturbance of the natural workings of the streams by overloading them with the material excavated from underground workings.

## TERRACE GRAVELS.

### DISTRIBUTION.

The highest gravel found in this district occurs on the east side of Gorge Gulch near its head, at an elevation of about 5,800 feet. Only a few pebbles of quartzite, well rounded, about 3 inches in diameter, constitute this occurrence, which therefore is not mapped.

The next highest mass of gravel, an extensive one which is shown on the map, lies on the top of the hill just north of Wallace. The summit of the hill is nearly 4,000 feet high, and the deposit is apparently about 500 feet thick. Doubtless belonging to the same stage of valley filling is the northeastern part of the long strip of gravel that caps the divide between Canyon and Ninemile creeks below Bradyville. The loose quartz bowlders here have withstood disintegration better than the underlying rocks, and as these have been sapped, extensive talus-like masses of the gravel have crept down on either side, especially into the heads of the gulches on the west.

The great bulk of the terrace gravels rests at elevations of 3,450 to 2,400 feet. In some valley sections this material lies on several distinct terraces, but elsewhere, though possibly once separated, it mantles the slopes continuously through a vertical distance of several hundred feet. The most extensive deposits that lie south of the river near Kellogg have their highest limit at about 3,000 feet, and descend within about a hundred feet of the floor of the valley. The mass just west of Big Creek was formed by the filling in of a channel about 500 feet deep. The largest area in the drainage basin of the North Fork of the Cœur D'Alene lies northwest of Murray (see Pl. VI, *B*, p. 34), between the 3,500- and 3,250-foot contours for the most part, although a lobe descends to 3,000 feet, and the other areas of the "old wash" near Murray have about the same range of elevation. A small patch of gravel on a spur in the North Fork Valley, at an altitude of nearly 3,500 feet, 2 miles west of the mouth of Cedar Creek, is the only mappable remnant of what may have been an extensive flood plain. On the slopes to the west scattered pebbles are present at about the same level. Another patch at 3,500 feet occurs on the spur between Scott Gulch and White Creek, in the Beaver Creek basin.

Lower deposits occur at various points, generally on terraces distinct from the present valley bottoms. The area east of Willow Creek, however, merges into the present bottom.

The best exposures of the terrace gravels occur on Prichard and Eagle creeks, where hydraulic mining was once an important industry.

### CHARACTER.

The terrace deposits consist mainly of well-rounded pebbles and bowlders of the old sedimentary and igneous rocks of the district. The prevailing kind of rock varies according to locality, but on the whole there is naturally a predominance of sandstone and quartzite. A large amount of decomposition is manifested in the banks of gravel at Murray, where bowlders of apparently firm quartzite break under the hammer with little more resistance than clay. This softening is doubtless due to the alteration of the sericitic cement by percolating waters. The worked deposits contain a large amount of secondary iron oxide, which gives them an orange color in a distant view.

Cementation is rarely observed, but has occurred locally and to a small extent. Iron oxide is the principal cementing material.

## GLACIAL DEPOSITS.

### DISTRIBUTION.

The small alpine glaciers that carved the high amphitheaters have all left morainal deposits, but generally these are of so little extent that they were not mapped. Some of these minor moraines are indicated, however, on Willow Creek, Gold Creek, Gorge Gulch, and elsewhere.

A few glaciers, formed by the confluence of several small ones, extended down into the large canyons, and attained a length of several miles. The larger ones occupied the canyons of Glidden, Prospect, and Canyon creeks, and of the upper St. Regis River. These glaciers, especially the last named, have left extensive and voluminous deposits, which lie mainly in the bottoms of the valleys, though small remnants and scattered bowlders on the sides indicate the former depth of the ice.

A few localities where the character of the glacial materials can be well observed may be mentioned. A good exposure of glacial débris has been made by the cutting for the road in Gorge Gulch. A conspicuous accumulation of white quartzite bowlders, little rounded and too large to have been transported by streams, lies on the purple and green beds of the St. Regis formation east of Rabbit Gulch. The best locality in the district for the study of the glacial débris is in St. Regis Valley, where the road winds about among irregular knolls and ridges of quartzite bowlders, and the railroad affords several cross sections of the moraines. There is usually some morainal material on the outward borders of the rock basins that hold the tarns in the amphitheaters. The artificial dam of Lower Glidden Lake has done little more than to repair the breach in the morainal dam that has been made by the stream since glacial time. The meadows near the head of Canyon Creek have been formed by the filling in of basins inclosed by morainal material, in which the stream has intrenched itself below.

### CHARACTER.

Topographically, the glacial accumulations are distinguished from stream deposits by very irregular surfaces. No well-developed longitudinal morainal ridges were noted in the district, but low ridges athwart the courses of the glaciers occur, marking stages in the retreat of the ice.

The glacial débris consists of an unassorted mixture of material ranging from fine sand to large bowlders. The bowlders, some of them much larger than those rolled by streams, are imperfectly rounded, and in some places where they have been protected by weathering show the characteristic glacial polish and striation.

## VALLEY ALLUVIUM.

### DISTRIBUTION.

As may be seen from a glance at the map, the large streams of the district have in general formed the broadest alluvial deposits. The rule, however, has many exceptions, the North Fork of the Cœur d'Alene, for example, having on the average a narrower flood plain than the South Fork, and the latter flowing for several miles in a steep-sided canyon after having occupied in its upper and smaller portion a comparatively broad valley. These exceptions are partially explainable by the more rapid development of valleys in softer rocks, but are probably in part the result of more obscure causes, such as uneven uplift or stream capture. Alluvial benches of appreciable width occur along all the streams except the small and steep-graded headwater brooks, whose erosive activity is constant, and these flow over ledges of bed rock.

The alluvial deposits in certain valleys impress the observer as disproportionate in size to the present streams, which in their lower courses are not generally eroding bed rock. This disproportion is especially pronounced in the valleys of Beaver, Prichard, and Eagle creeks. Hydraulic and dredging operations in their bottoms have exposed heavy accumulations of well-rounded gravel, which these streams are certainly not depositing now to any considerable extent. The facts indicate a former period of rapid deposition in valleys deeper than the present ones, by overloaded streams much larger than those that now exist. This period probably belongs to the time when the glaciers were dwindling, and the streams were laden with glacial débris augmented by a large amount of the older gravel washed down from the terraces. More recent redeposition of old gravels has taken place elsewhere, notably on the fanlike area about a mile up Ninemile Creek from Wallace, which is composed chiefly of gravel washed down from the hill to the west.

### CHARACTER.

The material in the bottoms of the valleys exhibits considerable variation in character, depending chiefly on the amount of working over to which it has been subjected. The alluvium in the lower and broader parts of the valleys consists in the main of well-rounded gravel mixed with sand. In places, especially where forest is growing or has recently been cleared away, this is covered with a soil sufficiently deep for the raising of hay and vegetables. The pebbles and bowlders brought up by dredging or hydraulic operations on the lower courses of Eagle and Beaver creeks are conspicuously well rounded, and this may be due to the fact that the material has undergone two periods of working over, for the present valley alluvium was doubtless in large part derived from the washing down and rearrangement of the old terrace deposits.

A conspicuous instance of the rearrangement of old gravels occurs in the neighborhood of the cemetery on Ninemile Creek, which is situated in an unusually large and steeply sloping alluvial fan composed in great part of sand, gravel, and bowlders evidently derived from the old fluviatile deposit that caps the hill to the west.

The points where small streams enter the valleys of streams decidedly larger are commonly marked by alluvial fans, all of which, however, are not brought out by the contours of the topographic map. These fans, except in certain peculiar cases like that just cited, are in general composed of material which, not having been transported far, is but slightly rounded, imperfectly sorted, and indistinctly stratified. Such material, especially when derived from the argillaceous Prichard and Wallace formations, is richer in nutriment for plants than more thoroughly worked material, from which the more soluble constituents have largely been removed, and some of the more flourishing gardens of the district are situated on such alluvial fans, which in addition to their fertile soil have the advantage of being easily irrigated.

Near the former terminals of the glaciers there is considerable material consisting of slightly reworked glacial débris which, having been brought to its present position by flowing water, is mapped with the valley alluvium, but which retains in a measure the character of ordinary morainal material, being composed of subangular fragments imperfectly sorted and stratified. Material of such character is exposed in a cutting near Pottsville, and forms a considerable portion of the valley floor to the east.

Most recent, in general, of all the alluvial deposits of the district is the mine débris which forms a veneer covering extensive areas along the lower part of Canyon Creek and in the valley of the South Fork of Cœur d'Alene River below Wallace. The material consists of sharply angular fragments of rock, less than an inch in diameter, and mud of impalpable fineness, much of which remains suspended in the river to its mouth and settles to the bottom only when it reaches Cœur d'Alene Lake. This mud makes the water of the upper, swift-flowing part of the river gray and densely opaque, but the lower part of the stream, especially after dilution with the limpid waters of the North Fork, is more translucent and of a pea-green color.

Within the Cœur d'Alene district, the principal areas in which the tailings have been deposited are three in number. The first lies in the only broad-bottomed part of the valley of Canyon Creek. The deposit here is somewhat of the nature of a delta. In the constricted part of the canyon upstream from this expansion the forces of the stream, concentrated within a narrow channel, suffice for transportation of a heavy load, but a short distance below Gem, where the grade of the beds diminishes at the same time that the canyon walls recede, the waters slacken in velocity and, in times of high water at least, disperse themselves broadly, so that they deposit a large part of their surplus burden. The floor of this expanded portion of the canyon is a barren waste of gray shingle (jig tailings) through which project the dead stumps of trees.

A second equally desolate tract lies in the valley of the south Fork of Cœur d'Alene River above Osburn. Between Twomile Creek and Nuckols Gulch a dam has been constructed to retain the coarser part of the tailings that pass through Wallace. This material comes in large part from Mullan, but includes some which escapes from Canyon Creek.

Below this dam there is no very extensive deposition until, near Kellogg, an immense amount of débris from the Bunker Hill and Sullivan and Last Chance mines is consigned to the stream. With this material the greater part of Jackass Prairie is covered. Within a few miles west of the district the coarser part of the river's artificial sediment becomes completely settled, but the meadows in the broad lower valley are annually flooded and covered with a film of the fine mud which the water carries in suspension.

# CHAPTER III.—STRUCTURE.

## INTRODUCTORY STATEMENT.

The great and complex deformation of the Algonkian rocks of the Cœur d'Alene district has been effected in about equal measure by folding and faulting, and to a less extent by the development of cleavage and fissility. The monotony of the strata and the lack of readily traceable beds, together with the scarcity of good exposures in some large areas, make it impossible to work out the structure with anything like completeness. But two seasons in the field have yielded enough data for tracing the faults which have affected notably the areal distribution of formations, for recognizing most of the great folds, and for making some generalizations in regard to the character of the minor structural features.

The information obtained has been represented in part in the geologic map and structure sections of Pl. II (in pocket). The dips and strikes selected for plotting on the map are, first, those which express the great folds; second, scattered ones that show the existence of subordinate folds not possible to work out completely; and third, fairly complete series along short, well-exposed sections that have been studied in detail, to show the general character of the minor plications and the complexity which the structure locally exhibits.

The numerous and abrupt variations in strike shown on the map and even more conspicuously displayed in the field can not have resulted from a single manifestation of force, but there is no positive basis for discriminating several periods of deformation. The movements affected all the formations of the Algonkian system, but were finished before the Tertiary gravels were laid down, so that in this district at least there is no evidence to fix their age more definitely than as post-Algonkian and pre-Tertiary. In few places is one fault clearly thrown by another, and it is therefore impossible to assign one system of faults to one period and another system to another period.

That folds, faults, and cleavage have been in some degree contemporaneous and the work of the same forces is indicated by the fact that in any given area the prevailing strike of the beds, of the cleavage, and of the principal faults is approximately the same.

In the following pages devoted to structure some account will first be given of the folds. The general character of the faulting will then be described, and illustrated by numerous examples. The nature of the cleavage will then be discussed briefly. Finally a general analysis of the structure of the district will be attempted.

## FOLDING.

The rocks of the Cœur d'Alene region have been thrown into numerous folds, many of which, however, have been cut off by faults. The strikes are prevailingly northwest and southeast. In most parts of the district a dominant trend, which is that of the axes of the principal folds, is recognizable, and the strikes in various directions transverse to this trend are due to local flexure or mark the ends of pitching folds.

The great folds, traceable for several miles, are not very numerous. Among them are two anticlines which cross Big Creek, the one half a mile below the West Fork and the other half a mile above the East Fork. Another is a syncline in whose axis lies Granite Peak.

The reason for the lack of persistence of the folds is in many cases their pitching character. Of large pitching folds the Granite Peak syncline is an example, while Tiger Peak and Sunset Peak are both at the ends of pitching synclines. Examination of the dips and strikes along Gold and Bowlder creeks shows that most of the minor folds there pitch more or less decidedly, a condition which with the scarcity of exposures accounts for the apparent discordance in structure between the opposite sides of some ridges and canyons.

The angles of dip are generally moderate to high, and it is only in the northeastern and northwestern parts of the district that gentle dips prevail over large areas. On the other hand, dips approaching 90° are common and there are some great overturns. The most extensive and pronounced of these overturns has been traced along the south side of the Osburn fault nearly the whole distance from Wallace to Wardner, and causes the St. Regis to overlie the Wallace formation. An excellent section of the beds thus inverted is exposed in Lake Creek canyon. There clear proof of the overturn is seen in the fact that the sun cracks of the shaly Wallace beds are invariably on the north side of the laminæ of sedimentation. The lowest reverse dips, good exposures showing some of 30° and doubtful ones of 15°, are seen on the spur west of the lower part of McFarren Gulch. Other localities where the dips are reversed are about the head of Paragon Gulch, at the head of Sonora Gulch, and southwest of Snowstorm Peak.

Many of the folds are unsymmetrical, and show steeper dips on one side than on the other. Where this is so, the folds almost invariably lean to the north or east. The steeper dips are on the northern and eastern sides of anticlines, on the southern and western sides of synclines. Nearly all the overturns are to the north and east, the only known exception being that which occurs south of Snowstorm Peak.

Superimposed upon the folds hitherto discussed and indicated on the map, like ripples upon great sea waves, and far too small to be shown to scale on the structure sections, are the minute wrinkles shown in much of the slaty material, and most conspicuously in the banded rocks of the Wallace formation. Nowhere can one find more striking examples of these minor plications than along the valley for a few miles above and below Wallace. Some exposures of these intricate folds are shown in Pl. VII. Some of the railroad cuts display closely pressed folds a few feet across, complicated by faults. Many of the folds are so small that a hand specimen may show several, and in certain finely banded argillites in the upper part of the Wallace formation intricate folding and faulting is beautifully shown on a minute scale.

## FAULTING.

### EVIDENCES OF FAULTING.

In the Cœur d'Alene district the existence of a fault may be considered proved when a formation is found in contact with another not adjacent to it in the normal stratigraphic sequence, for within this area none of the formations disappear through unconformity or overlap. Evidence still more positive is obtainable in some underground workings, where many fault contacts may be directly observed. Lesser faults are indicated when formations in normal sequence show discordant dips on either side of the plane of contact. The outcrop of many faults is marked by a breccia, which may be very conspicuous where the faulted rock is quartzite. The quartzitic breccias, consisting of angular fragments stained and cemented with red iron oxide, in some places form crags and break down in rugged bowlder-like masses.

While it is on such criteria as these that positive demonstration of faulting must depend, the existence of a fault is frequently suggested by certain topographic features. The relatively rapid erosion that usually takes place in the crushed rock of a zone of fracture tends to develop stream valleys along fault lines, and to form saddles where the faults cross ridges. As in this district none of the formations have thick, persistent beds much softer than those above and below, a row of saddles, especially if aligned in a direction parallel to known fissures, may generally be ascribed to a fault. Again, an abrupt change of slope frequently proves to be the result of a fault which has brought together two formations that differ widely in resistance to erosion. The few faults that lack notable expression in the topography are those which have caused a hard formation to rest upon a soft one, as for example the gently dipping overthrust west of Ucelly Gulch, which has brought the Burke and Revett quartzites over the Wallace shales.

All these topographic indications of faulting have been brought about, so far as observed, through differential erosion. The district apparently affords no examples of direct expression of faulting in the topography. Where the surface of an upheaved block has a general elevation greater than that of an adjacent downthrown block, the fact is nearly always due to the greater resistance of the rocks on the side of the upthrow, and there are many instances of the opposite condition, where the surface of the downthrown block is the more elevated.

### GENERAL CHARACTER AND DIRECTION OF THE FAULTS.

Of the faults in this district whose direction of dip is known, the majority are normal, yet there are also many of the reverse type. The normal faults generally have steep dips of 50° to 80°. There is, however, an exception in the great Dobson Pass fault, whose dip is about 30°.

The reverse faults also vary greatly in dip. A part only, as the Ucelly Gulch and Carpenter Gulch faults, have the low dips generally considered characteristic of overthrusts; but a far greater number clearly seen in mine workings have dips of 50° to 80°, and although having displacements amounting to thousands of feet are accompanied by so little crushing and disturbance that it is impossible to conceive of their having been formed by lateral pressure alone. To these dislocations the term "overthrust," suggesting low dip and intense tangential strain, does not seem appropriate.

The throw of nearly all the faults indicated on the map amounts necessarily to hundreds or thousands of feet, for while multitudes of smaller faults doubtless exist, the conditions do not admit of their being traced.

In direction, most of the faults are in the northwest and southeast quadrants. There is one marked system of faults with directions approaching west-northwest, and with these many important ore bodies are associated. The system is best developed in the southern part of the district, but is represented by examples in all parts of it except the extreme northeastern. Faults with a nearly meridional direction, from north-south to north-northwest, are rather numerous, especially in the central and northern parts of the area. Near Burke is a well-defined group running about N. 40° W. A northeasterly trend is shown by a few faults in the north-central part of the district.

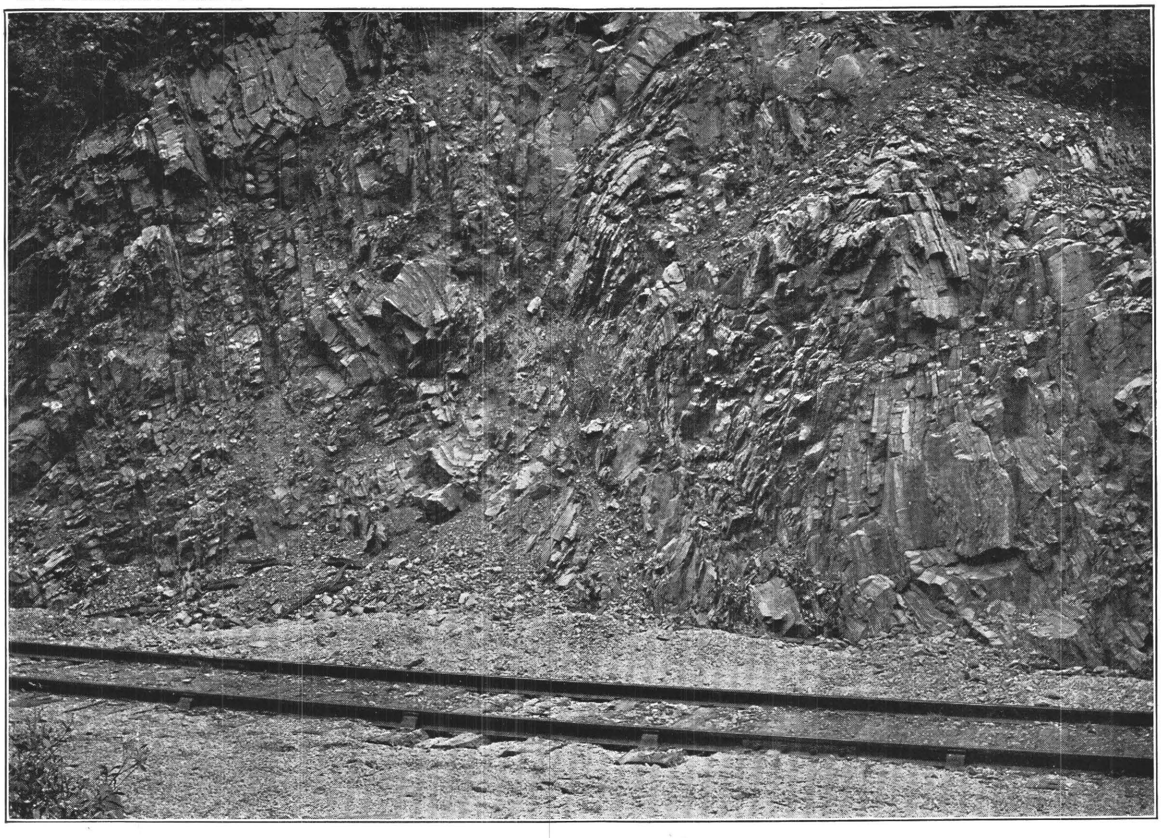
The major part of the faults, whether normal or reversed, have a westerly or southerly dip. The exceptional eastward or northward dipping faults occur chiefly east of Burke.

### DESCRIPTION OF PRINCIPAL FAULTS.

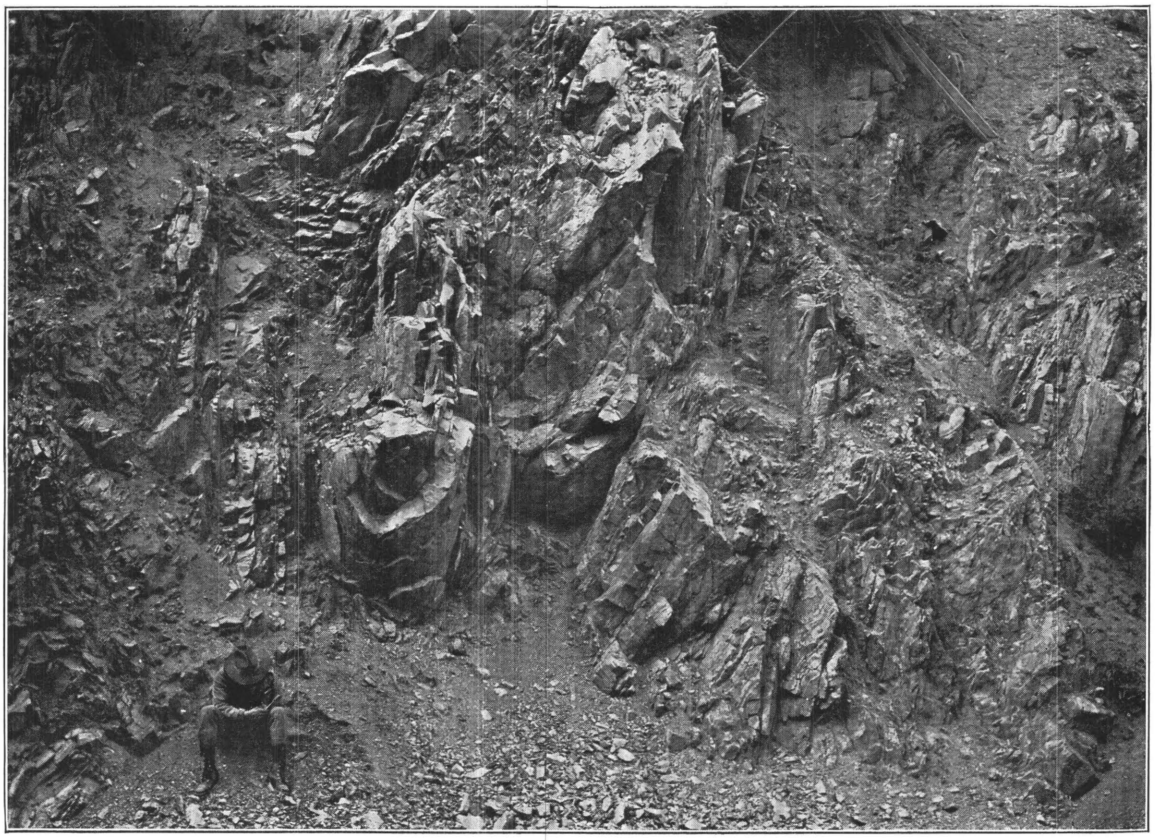
The dislocation which has been traced for the greatest distance will be designated the Osburn fault, from the village that lies in its course. This is a normal fault, with the downthrow on the south. It is distinctly traceable from Mullan to the western limit of the district, a distance of 18 miles, and reconnaissance observations indicate that it continues westward fully 10 miles more. It is exceptionally well expressed in the topography. Between Mullan and Osburn nearly every spur is deeply notched where the fault crosses. West of Osburn its course is marked by saddles or abrupt changes of slope, which characterize the line of its supposed continuation down the valley as far as Mission. From Osburn to Dexter Gulch it is traced almost exactly by the electric power line, which has followed the line of saddles due to the fault, rather than the more devious course of the river.

The throw probably reaches its maximum near Osburn, where beds at a horizon near the middle of the Wallace on the south are in contact with beds low down in the Prichard formation on the north. The displacement here must be considerably more than 6,000 feet. The throw decreases eastward from Wallace, but is still large where the fault disappears beneath the alluvium. At Wardner it is diminished by a cross fault which cuts off the Wallace. West of that point the Osburn fault is generally between Burke and Prichard rocks.

The Osburn fault was observed underground in several places. It is crossed by the No. 6 Morning tunnel and, as noted by Mr. Ransome on page 171, a tunnel is being driven along it in Grouse Gulch. It is also well seen in the Three Sisters mine near Wallace. In all these places



*A*. LOCAL FOLDING IN WALLACE FORMATION, ONE-HALF MILE EAST OF WALLACE.
Shows typical thin banded beds.



*B*. SHARPLY FOLDED AND FAULTED BEDS OF THE WALLACE FORMATION, 1½ MILES EAST OF WALLACE.

the fault plane shows a steep dip to the south. A prospect a little west of the mouth of Rosebud Gulch has crossed the fault, but the tunnel is caved in just north of it. The property shows, however, a basic dike 80 feet thick, apparently injected into the fault fissure. A drift has been run several hundred feet along the north side of the dike, in a zone of crushed rock several feet wide, with many slips and seams of gouge. None of these fractures are very regular or persistent, but most of them dip to the south. The movements along the fissure have been complex in detail, and some of them have affected the dike. In the adit the Burke and Prichard north of the fault are cut by a multitude of minor slips dipping steeply to the south, which increase in number as the main fault is approached. There has been a distribution of the movement across a zone several hundred feet in width, but the throw along the main fault seems to have been of an order of magnitude distinctly higher than that on any of the subsidiary fissures.

Another fault of great length probably influenced the location of Placer Creek, and will be referred to as the Placer Creek fault. It enters the district on the west just south of the East Fork of Pine Creek, and is plainly marked for 12 miles eastward. It disappears under the alluvial bottom of Placer Creek, but there is evidence that the fissure continues for fully 30 miles farther east, in the existence of the great dike already referred to, and a zone of mineralization in line with its general course. No fault in the district has more complete topographic expression, or is more readily traced. Half a dozen distinct saddles, including the one behind Kellogg Peak, mark its course. From the summit marked "5473" in Pl. II (in pocket) southwest of Wallace, a view to the southeast along this fault shows a sharp peak carved from hard quartzites, whose northward-dipping strata are abruptly cut off by a plane of steep southerly dip which separates them from the smooth brush-covered slopes of soft Wallace shale. A very similar knob of quartzite, cut off on the south by the fault, lies between the forks of Big Creek.

Underground observations on the Placer Creek fault were made in the Highland Chief mine, and in a prospect on the west side of Big Creek. In the latter a gouge about 3 feet thick was noted. In both places a steep south dip was observed, which, as the downthrow is on the south, makes the fault a normal one.

The throw of this fault is probably near its maximum east of Big Creek, where it brings Striped Peak beds against Revett, and must there be at least 6,000 feet.

A fault crossed by the Alhambra tunnel on the West Fork of Elk Creek may be called the Alhambra fault. It is the first recognized instance of the steep reverse faults of which several examples were found later. It has been traced only from Wardner to the slope west of Big Creek. Its direction for a mile and a half from Wardner is about S. 50° E., and it then changes to about S. 75° E. Along most of its course the fault brings Revett quartzite over Wallace shales, and its maximum throw is probably not far from 2,000 feet. It is not strongly expressed in the topography, but breccias in the quartzite may be seen all along its course.

The fault is crossed by the Alhambra tunnel about 1,300 feet from the portal. In the outer part of the tunnel are shaly Wallace rocks, minutely wrinkled but with a gentle average dip. Near the fault the strike of the Wallace is N. 80° E. and the dip 50° to 60° S. The quartzite 50 feet farther south is vertical and strikes N. 70° W. The fault is remarkably clean cut, with but a few inches of gouge, and there are no evidences of intense disturbance in the rocks on either side. The dip of the fault plane is about 50° S.

At the eastern end of its known outcrop the Alhambra fault is joined, by a fault extending nearly north and south, to another fault with a direction nearly east-southeast, which is a steep reverse fault of the same type. This dislocation, designated the Big Creek fault, extends eastward to Placer Creek, and is exposed in a prospect on the west fork of that stream. There its dip is about 65° S. It is remarkably clean cut, and there is but a few inches of gouge between its walls.

In the eastern part of the district, one of the most important west-northwest faults, though of far smaller throw than those already described, extends along the face of the hills from Canyon Creek to Gentle Annie Gulch. Its trace as it cuts the spurs shows it to have a southerly dip, and to be, therefore, reversed. North and northeast of Mullan it is marked by an abrupt transition between the quartzite and the softer St. Regis beds, here very strongly sheared. On the south the fault is partly bordered by a hard stratum of quartzite known as the White Ledge so that the dislocation may be called the White Ledge fault.

Among the numerous faults in the vicinity of Burke, the one most deserving of notice is the O'Neil Gulch fault, another steep reverse fault with a dip of about 75° E. Part of it runs almost exactly north and south, but the southern part turns about S. 40° E., the change of direction being indeed in an angle that may signify the intersection of two different fractures. Noteworthy is the closeness with which O'Neil and Gorge gulches follow this dislocation. Yet there is no conspicuous evidence of this fault at the surface, and it was first discovered underground. It causes the repetition of a great thickness of Burke rocks, which on both sides dip eastward at about the same angle. Only a thin wedge of Prichard is poorly exposed at the surface on its eastern side.

The great Dobson Pass fault, whose general direction is a little west of north, has determined a line of depression across the central part of the district, and the lowest pass between the North and South forks of the Cœur d'Alene. It is traceable from a point about half a mile south of Bradyville northward to Trail Creek. At the south it dies out in an area where exposures are poor, while at the north it is lost in an area of complex faulting.

The Dobson Pass fault is normal, and dips gently westward. Its throw is probably greater than that of any other fault in the district. At Dobson Pass it has brought the Striped Peak beds against the Prichard, which necessitates a displacement on the fault plane of more than 8,000 feet. The trace of the fault on the surface has some abrupt jogs which indicate that it has been thrown by minor cross faults, and which are, of course, the more evident because of the low dip of the older fault.

The tunnel of the Ninemile Mining Company has crossed this fault, and gives opportunity to observe the character of the fault zone. The country rock east of the fault is monzonite with inclusions of metamorphosed Prichard; that to the west is Wallace slate. The contact is about 1,000 feet from the portal. The fault fissure or shear zone has a fairly definite foot wall of syenite striking about N. 15° to 20° W. and dipping about 35° W. West of this is about 12 feet of clayey material succeeded by shaly rock extremely mashed but recognizable as Wallace. About 24 feet farther west a much decomposed porphyry comes in, which alternates with Wallace rock in the outer part of the tunnel. All along the tunnel there is intense disturbance and evidence of many minor faults.

The Panhandle tunnel also crosses the Dobson Pass fault near its face, where Revett quartzite is brought against monzonite and a basic dike rock. The fault plane there also has a very low west dip, but the gouge is only a foot or less in thickness.

The Carpenter Gulch fault is an overthrust with a rather gentle dip, which has been traced for about 12 miles. From the northern boundary of the district the fault trends nearly due south to a point about one-half mile southwest of bench mark 4630, at the head of Moon Creek, where its direction changes rather abruptly to about S. 35° E., and this direction is maintained to a point near Twomile Creek, beyond which the fault can not be followed. The fault is well expressed in the topography and can be traced for the most part with considerable accuracy. The mapping shows that its dip is west and south at a moderate angle and that it is steeper at the north than at the south. Its throw is probably about 2,000 feet along most of its course as traced. West of the mouth of Prichard Creek it has thrust Revett beds over Wallace; west of Twomile Creek it brings Prichard over Burke, the two formations being strongly discordant in dip and strike.

It is on the knob west of the mouth of Carpenter Gulch, however, that the fault is best exposed. The top of this knob is Revett quartzite, which is underlain on the southeast slope by St. Regis beds. The two formations are seen in place within about 50 feet of one another at one point. They differ but slightly in attitude, and although there is some brecciation along the contact there is no evidence of great disturbance in the fault zone.

## CLEAVAGE.

### CHARACTER.

The rocks of the Cœur d'Alene district almost universally exhibit cleavage. Its perfection varies for different kinds of rock and for different parts of the district. At any given locality it is best developed in the finer-grained slaty rocks, showing perhaps the greatest perfection in the green slates of the lower Wallace, which are homogeneous and without strong shaly partings. In some of the purer quartzite it is not developed at all, but in the sericitic quartzites it is generally distinct. In rocks of similar composition the cleavage varies according to locality, being on the whole best developed where folding and faulting have been most intense. Under the most favorable conditions, however, none of the Cœur d'Alene rocks show cleavage approaching in perfection that of roofing slates; when struck with the hammer they usually break along curved surfaces intersecting at small angles.

Microscopic study, as already indicated, shows that this cleavage is due to the development of minute scales of sericitic mica lying nearly parallel. It is believed that the cleavage planes are normal to the maximum pressure, and that the cleavage of these rocks is flow cleavage as defined by Leith.[a] Slipping along cleavage planes has occurred at many points, however, and has given rise to an imbricated structure on the surfaces of slabs split parallel to the bedding.

### ATTITUDE.

The attitude of the cleavage is far less variable than that of the bedding. In a given place it is commonly about parallel to the principal fault planes. Its strike is the same as the prevailing strike of the rocks, but its average dip is steeper than that of the bedding. Accordingly, in the southern part of the district it generally shows a strike near north-northwest and a steep dip to the south; in the central, eastern, and northeastern parts a strike near north and south, and a steep dip to the west. But local exceptions to the rule are not uncommon. North and east dips are occasionally seen, and cleavage with a low dip occurs in places, as for example west of the lower part of Big Creek, where it dips 30° S. In the overturned Wallace west of McFarren Gulch, where the reversed dip of the strata is 30° S., the cleavage dips 15° S. Along Moon Creek several observations show cleavage about parallel to the course of the stream, at a large angle with the strike of the rocks, and with a dip of 30° to 45° NW.

A fact worthy of note is the general discordance, more marked than in most regions, between cleavage and bedding. The significance of this fact appears to be that the rocks underwent deformation under a great load of later strata that have since been removed, so that the great pressures that produced slaty cleavage were unable to compress the strata into closed folds.

## STRUCTURAL SUBDIVISIONS OF THE DISTRICT.

### POSITIONS AND BOUNDARIES OF SUBDIVISIONS.

The structure of the district is so complex that reduction of the many facts to a simple, general, and easily understood statement covering the whole area is perhaps not possible. It may be useful, however, to make a division of the district into more or less definite structural provinces, and to point out the leading features of each. The locations of the divisions made for this purpose, and the names under which they will be described, are as follows

1. The southwestern area, west of the center of the district, bounded on the north, east of Osburn, by the Osburn fault, and west of it by the river.

2. The southeastern area, east of the southwestern, bounded on the north by the Osburn fault and the South Fork of Cœur d'Alene River.

3. The eastern area, bounded on the west by part of the Dobson Pass fault, and on the northwest by a line extending from Dobson Pass northeastward to the edge of the district.

[a] Leith, C. K., Rock cleavage: Bull. U. S. Geol. Survey No. 239, 1905, p. 23.

4. The northwestern area, northwest of the eastern, the northern boundary passing through Kings Pass and tangent to the Murray Peak area of the Burke formation.

5. The north-central area, north of the northeastern, extending westward to the Carpenter Gulch fault.

6. The central area, bounded on the west and east by the Carpenter Gulch and Dobson Pass faults and their continuations, and extending from the mouth of Beaver Creek to 1½ miles south of Bradyville.

7. The northwestern area, west of the central and north of the southwestern.

## SOUTHWESTERN AREA.

In the southwestern area the structural trend is west-northwest, except in the area south of the Placer Creek fault and west of South Fork of Big Creek. The most important elements of the structure are the series of great faults trending from east-west to northwest-southeast. Of five of these whose attitude is definitely known, all dip rather steeply to the south; three of these are normal, but two are reversed. There is a noteworthy general convergence of these faults toward the east, and three actually merge near the bend of Placer Creek. Several folds may be traced for long distances. Those best defined are (1) the overturned south limb of a syncline cut off by the Osburn fault, traceable from Wallace to Wardner; (2) an anticline between the Polaris and Big Creek faults; and (3) an anticline south of the Placer Creek fault, traced from Big Creek eastward to Placer Creek. West of Big Creek this last-named fold seems to pitch upward and die out, but the area where this occurs is poor in exposures. The axial planes of all these folds dip toward the south.

The structure is most complex and also most obscure in the quartzitic rocks near Wardner. Here the mapping must be considered as greatly generalized.

## SOUTHEASTERN AREA.

The general structure of the southeastern division is that of an anticlinorium whose general trend is a little north of west. This comes out well in the mapping, and a general pitch to the west is shown by the fact that the St. Regis area narrows to the west and finally leaves the Wallace formation in occupation of the whole width of the belt. The many small folds included in the anticlinorium are indicated by the sinuosities in the southern boundary of the St. Regis area, as well as by the plotted dips and strikes. The structure is obscure along the ridge forming the State boundary in the eastern part of this division, the deformation being complex and the exposures poor, and the boundaries of the Wallace areas here are not well determined. The southerly dips in the decomposed shales along the railroad are interpreted as reversed, the best evidence of overturning being shown by the plotted dips near Dorsey. Farther east, however, the structure is more in doubt.

The area has few proved faults. Except for two doubtful north-south fractures, all those found have a nearly east-west direction. Of the two best determined, one is a normal fault crossing Boulder Creek near the middle, and seen in the Little Giant mine to the east; the other is a steep reversed fault about a mile north of Stevens Peak.

## EASTERN AREA.

The eastern area is rather the most complex of all the divisions, and has no very marked unity. It is pretty distinctly separated from the southeastern area at the west by the Osburn fault, but to the east the boundary adopted is not defined by any sharp change in structural character. The prevailing trend of the folds is nearly north and south, but the strikes exhibit much variation. The numerous faults belong to three distinct systems whose directions are approximately (1) north-northwest, (2) N. 40° W., and (3) north and south. The structure is most complex in the western part, and least so in the northeastern part.

The folds in the western part of the area are so broken as hardly to be recognizable, and there is great irregularity of strike. West of Gorge Gulch Canyon Creek crosses an anticline and a syncline, both pitching to the south. Tiger Peak is at the end of another syncline that pitches to the northeast, and the sculpture of its amphitheater, into which the beds dip on all sides, has probably been influenced by this structure. The head of Granite Gulch affords a good section of a southward-pitching anticline, somewhat complicated by minor folds, which dies out a mile or so farther south. East of this is seen a fold, one of the greatest and most completely worked out in the district, which may be designated the Granite Peak syncline. On the north it abuts against a fault near Sullivan. It may be followed southward 7 miles to the forks of Deadman Gulch, where the western limb, much broken by faults south of Canyon Creek, finally becomes indistinguishable, and the eastern limb swings about toward the east. It pitches to the south and is unsymmetrical. Its western limb is the steeper, and is strongly overturned at the head of Sonora Gulch, its form here being shown on section D–D′ of Pl. II (in pocket). This syncline is flanked on the east by an anticline, pitching strongly to the south, which is limited at the north by the Thompson Pass fault. Thence to the Snowstorm fault, this fold is strongly marked, but farther south its crest flattens and the limbs gradually approach the north-northwest trend of the southeastern area. The dips there become steep and are even overturned in places at the heads of Gentle Annie, Daisy, and O'Brien gulches. In the area north of Thompson Pass is another southward-pitching syncline, whose western limb is partly overturned and broken by a reversed fault.

West-northwest faults characterize the southwestern part of the area. Three of these form a group near Mullan. The two to the north, the White Ledge and Hunter faults, are distinct, but the lesser one to the south is obscure. A somewhat notable series of step faults is developed south of Gem. The others of the west-northwest system worthy of notice are the Snowstorm fault, one of the steep reversed type, and the conspicuous Thompson Pass fault, which has a throw of at least 5,000 feet.

The group of faults trending about N. 40° W. lie along the south side of Canyon Creek. The one south of Burke, seen in section in the Morning tunnel, shows an eastward dip and is therefore normal. The Sonora fault, which is one of large displacement, is yet not conspicuous except for a small part of its course. It seems to be an overthrust dipping rather gently to the west.

The north-south faults are developed north and east of Burke. The O'Neil Gulch fault, a steep overthrust dipping to the east, has already been described, and the one along French Gulch is another of the same type, with a dip of 65° to 80° E. The north-south fault north of Thompson Pass, on the assumption that it is a plane, is shown by the form of its trace to be an overthrust dipping about 60° W.

In regard to this division as a whole, it may be observed that though the faults with throws in different directions about compensate each other, the southward pitch of nearly all the folds gives the aggregate effect of a tilting to the south, as is shown by the areal distribution of the rocks. The Wallace formation is developed only at the south, whereas to the north the prevailing formations are Revett and Burke, which finally give way to the underlying Prichard.

### NORTHEASTERN AREA.

The northeastern area is the most extensive one in which no faults are mapped, but as it is almost entirely occupied by the Prichard formation, it will readily be surmised that this is due in part to lack of the certain evidence given by the discordant contact of different rocks, and that the area may be cut by faults attaining considerable throw and yet bounded on either side by beds of this great accumulation of argillites. Indeed, brecciation and lines of saddles are found frequently enough to show that faults are not absent. Again, the straight sections of which the zigzag course of Prichard Creek is made up, unrelated as they are to the strike of the rocks, strongly suggest that the stream has intrenched itself along zones of fracture. Confirmation of this suggestion is found in the fact that for a mile and a half east of Raven the valley is in line with a determined fault. On the other hand, faults of the greatest magnitude would have let masses of later rocks down into the Prichard and so have been mappable.

The strike in this area is prevailingly a little west of north. Some of the greater folds can be traced for a number of miles. The Sunset Peak syncline, for example, is indicated by the dips as far north as the head of Tiger Gulch, and the Granite Gulch anticline seems to continue northward about 5 miles from the Burke boundary and then to die out near the mouth of Butte Gulch. Another anticline is shown by the dips from the ridge north of Bear Gulch southward to Prichard Creek near Sullivan. The lamprophyre dike north of Bear Creek suggests, however, that this arch may be broken along its crest. In addition to these greater folds, there are many smaller and less regular ones, especially about Murray, where the dips of scattered exposures have little semblance of system.

### NORTH-CENTRAL AREA.

In the north-central area, as in the area last described, the structural trend is nearly north and south. The principal tectonic features are three great faults. The one west of Murray Peak, which is of unknown dip, has a throw of at least 3,000 feet. The other two, which, converging northeast of Kings Pass, form two sides of a block of Wallace let down into the Prichard and Burke rocks, are of far greater displacement. The attitude of the eastern fault is not known. It is not very well exposed, and it could not be traced with accuracy across the gravel-covered area northwest of Murray. The Ucelly Gulch fault, clearly an overthrust, is better worked out. Just east of Eagle the point where it crosses the spur and the points where it disappears beneath the alluvium were carefully plotted, and the plane determined by them was found to dip 26° W.

The structure of the quartzite masses is simple, and appears on the map, but the slaty rocks have suffered folding which is too complex to be worked out with any completeness, and whose character is indicated in a measure by the plotted dips.

### CENTRAL AREA.

Disregarding details, we find the central area to be essentially a sunken block tilted gently eastward, and bounded by two curved zones of faulting that converge at the ends. A section from the head of Terror Gulch to the mouth of Pony Gulch shows an eastward-dipping monocline between two faults, without important complications. Toward the ends of the area, however, the structure is extremely complex.

The western boundary of the block is formed mostly by the Carpenter Gulch overthrust. Not far southeast of the point where this fault is lost, its place is taken, as it were, by the Black Cloud overthrust, which nearly or quite meets the Dobson Pass fault. The Dobson Pass fault forms the well-defined eastern limit of the dropped block as far north as Trail Creek, and may be thought of as continued by the most persistent of the northwesterly faults north of Delta. This last-named fracture can not be traced to actual junction with the Carpenter Gulch thrust.

Each of the great limiting faults is accompanied by subsidiary faults of smaller length and throw. Several nearly parallel to the Dobson Pass fault, and with the throw in the same direction, are mapped, but there are topographic suggestions of others in both the Wallace and the Prichard areas. The appearance of enormous thickness in the Wallace rocks of the Beaver Creek basin is perhaps due to repetition by step faults of this system not possible to locate. The Carpenter Gulch fault likewise has its company of auxiliary dislocations, of which the clearest examples are seen west of Beaver Creek. The dips of these minor faults, which are mostly downthrown on the east, are not known, but as fissures exposed in a prospect on Alder Creek, in line with the first fault west of Delta, dip to the west, it seems probable that this fault at least is reversed.

There are a few minor faults transverse to the principal ones, and some, of slight throw as compared with most of those shown on the map, are conspicuous because they have thrown the Dobson Pass fault. If this has a dip of 30°, it is evident that the jog produced by a cross fault is twice as great as the vertical displacement.

Two of the most complexly faulted areas in the district lie near the ends of this depressed mass. Although examined in detail, neither area can be mapped with great accuracy, for the exposures are far from satisfactory.

## NORTHWESTERN AREA.

If, as was the Beaver Creek area, the tract west of it is viewed without noting details, its structure is found to be essentially that of a very broad anticline pitching decidedly to the north. The crest runs nearly due north from a point near the mouth of Moon Creek, and the prevailing dips are everywhere away from this point. The general anticlinal structure is clearly expressed by the areal distribution of the rocks. The Prichard forms a roughly triangular area at the south, and to the north of it higher and higher formations, up to the Wallace, prevail in succession. The eastern limb of the anticline has been partly broken by the Carpenter Gulch fault, which, however, has not greatly affected the areal distribution of the rocks south of Alder Creek, and there the northwestern and central divisions, if defined in terms of characteristic structural features, may be said to overlap.

On a closer view, we find this dominant anticlinal structure modified considerably by minor folds, and still more by faults. A small anticline is clearly developed near the western limit of the district; there are local dips transverse or opposed to the general dips in the great area of Prichard, and many minor flexures occur along the North Fork of the Cœur d'Alene, where indeed the great fold is apparently dying out. A series of northwesterly faults has been worked out in the western part of the area. The two farthest south show relative upheaval on the south side, but the four to the north are a series of step faults with downthrow on the south, and are responsible for the great width of outcrop of the northward-dipping quartzites. Some of these faults, as indicated on the map by dotting, are obscure and perhaps not accurately located. It is almost certain also that to the east, where the thickness of northward-dipping Burke is apparently abnormally great, there are other similar faults, but as they are walled on both sides by poorly exposed beds of sericitic quartzite they could not be traced. Three north-south faults were detected, the one north of Cedar Creek having, though not conspicuous, a displacement of more than 2,000 feet.

# CHAPTER IV.—GEOLOGIC HISTORY.

## INTRODUCTORY STATEMENT.

The record of the earliest events in the history of the great geologic province in which the Cœur d'Alene district lies is not to be found in the district itself, but is preserved in the gneisses and schists exposed near Cœur d'Alene Lake, if these, as seems to me probable, are of Archean age. These rocks are an intricate mixture of highly metamorphosed sedimentary and igneous material. From them it appears that in pre-Algonkian time a series of sediments was laid down, that they were invaded by siliceous magmas, that after these cooled as granitoid rocks the whole complex, subjected to great pressure and intense heat, was thoroughly recrystallized and foliated. The metamorphic rocks then became a land mass probably of vast extent but not of great elevation, and were exposed to erosion.

The detritus formed by their degradation began to be deposited, probably, in a shallow sea to the east. The earliest strata thus laid down have not been identified, and have probably been dropped below the zone of observation by faulting. They may be represented by conglomerates found in British Columbia west of Kootenai Lake. The quartzitic sediments exposed in close proximity to the gneiss near the town of Cœur d'Alene on the western shore of the lake of that name may be stratigraphically lower or they may be equivalent to the lowest strata in the Cœur d'Alene district. The series of Algonkian rocks in this district form an incomplete record of the eon of quiet sedimentation thus initiated. In other parts of the region there are several thousand feet of Algonkian beds younger than any found here. There are also remnants of post-Algonkian strata, which may or may not have been deposited in this area, so far as our knowledge indicates, for a vast portion of the record has been destroyed by erosion.

There is therefore an indefinitely long period following the time when the highest of the Striped Peak beds were deposited, in which no dates can be fixed. Within this space of time there were intrusions of monzonite. Perhaps in part contemporaneously with this period of intrusion, but in part subsequently to it, the great deformations of the strata occurred, with the intrusion of basic dikes. The regional metamorphism which the Algonkian rocks have suffered was doubtless connected in part with the intrusion and deformation.

After these things were accomplished, we know that a great amount of erosion took place, and of its later stages we may read something from the present forms of the land surface and the character of the surficial deposits of the valleys.

The geologic history thus outlined may be conveniently divided into three periods—(1) Algonkian sedimentation; (2) intrusion, deformation, and regional metamorphism; and (3) development of the present topography.

## PRE-CAMBRIAN SEDIMENTATION.

### GENERAL CONDITIONS.

The facts that shed most light on the general conditions under which the Algonkian strata were deposited are (1) the fineness of their materials, none being coarser than fine sandstone; (2) the presence of such features as sun cracks and ripple marks in most of the formations; (3) the conformable sequence throughout a great thickness of strata; and (4) the gradual transitions from one formation to another. These facts respectively indicate (1) that the land from which the sediments were derived was of low relief and eroded slowly; (2) that the deposition took place in great part on vast mud flats frequently exposed to the air; (3) that the accumulation was not interrupted by orogenic movements; and (4) that there were no very abrupt changes in the conditions of sedimentation. These phenomena might be explained on the hypothesis that the Algonkian era in this region was characterized by gradual subsidence, which during much of the time kept exact pace with deposition. The constant maintenance of conditions favorable to the formation of shallow-water features for the enormous length of time required for the deposition of many thousands of feet of fine-grained sediments is a thing unparalleled, so far as I am aware, in any other geologic system. The Algonkian rocks of the Grand Canyon, however, are similarly marked in considerable part by shallow-water features. The thought suggests itself that in that remote age the crust of the earth was much less rigid than it has since become, and that it responded with great sensitiveness to changes of load, or in other words that it maintained a high degree of isostasy. This hypothesis, however, postulates a delicacy of balance between deposition and subsidence which it is extremely difficult to conceive if it be further assumed that the Belt sediments were deposited in a basin connected with the open sea. But the difficulty is much diminished if it be supposed that the conditions of deposition were essentially continental, and that the water was kept shallow by evaporation from a vast inland lake, or that the sediments were deposited by meandering rivers upon a great delta plain.[a] It still appears necessary, however, to assume a very great and rather gradual subsidence during the accumulation of the Belt rocks.

The successive formations of the Cœur d'Alene district were deposited under somewhat varying conditions, as may be shown by considering each in order of age.

### PRICHARD EPOCH.

The main body of the Prichard formation was accumulated in a moderate or considerable depth of water. A large amount of carbonaceous material, whose source is difficult to conjecture, was incorporated in its sediments. In the last stage of its deposition the water shoaled and the conditions that prevailed during the Burke period were initiated.

### BURKE EPOCH.

The sediments now became somewhat more siliceous and poorer in carbonaceous particles. Mud-flat conditions, evidenced by ripple marks and sun cracks, were maintained throughout the period, in the latter part of which there was a gradual passage to the conditions of the next period.

### REVETT EPOCH.

The Revett sediments have been more thoroughly worked over than those of any other formation, and this was presumably accomplished by the beating of waves upon a shore. It seems probable that the area suffered a slight and gradual subsidence at the close of the Burke period and that a beach formed on the western shore of the sea and migrated eastward. The sands washed and rolled by the waves were in part carried out to sea and formed gradually thinning layers extending some miles east of the beach at any given stage. In harmony with this hypothesis is the fact of a gradual eastward thinning of the Revett quartzite in this latitude. It is apparently thicker in the western than in the eastern part of the district. Near Eddy, on the Northern Pacific Railway, in longitude 115°, the formation is much thinner and less sharply differentiated from the shallow-water beds above and below than in the Cœur d'Alene district, while in longitude 114° 30′, on the divide between Missoula and Flathead rivers, there is none of the hard quartzite that is most characteristic of the formation.

### ST. REGIS EPOCH.

In the latter part of the Revett period, either by shoaling due to sedimentation, by gradual elevation of the land, or by recession of the water, mud-flat conditions returned and continued during the St. Regis period. The considerable amount of iron oxide, free or in combination, which these rocks contain has some significance regarding the conditions of their deposition.

[a] See Barrell, Joseph, Relative geological importance of continental, littoral, and marine sedimentation, part 3: Jour. Geol., vol. 14, 1906, pp. 524-566.

It is taken as probably indicating that in the preceding periods the dry land to the west had become so thoroughly planed down that stream erosion could not keep pace with the accumulation of waste, and that at the beginning of St. Regis time this senile togography was rejuvenated by uplift of the land, so that the streams began to wash down and to deposit on the mud flats the mantle of oxidized reddish soil.

### WALLACE EPOCH.

The characteristic features of the Wallace formation are the presence of abundant carbonates of lime, magnesia, and iron, together with all the signs that these materials were deposited on mud flats frequently laid bare to the sun's rays. Though in this district the Wallace has yielded no organic remains, fossils have been found to the northeast and east by Walcott and by Willis in corresponding formations. The failure to find them here may have been due to greater alteration of the beds. There is no evidence to show, however, that organisms were abundant in Wallace time, or that the carbonates in the Wallace rocks were chiefly secreted by organisms. It appears more likely that they were precipitated by evaporation, determined by a shutting off of the basin of deposition from the great seas with which it was presumably connected in the preceding periods by rivers or by straits. The reestablishment of the connection marked the opening of the Striped Peak period.

### STRIPED PEAK EPOCH.

The conditions of the Striped Peak time must have been practically identical with those under which the lithologically similar St. Regis formation was laid down.

## INTRUSION, DEFORMATION, AND METAMORPHISM.

### INTRUSION.

The mode of intrusion of the syenite is to be learned, if at all, from its chemical and physical relations to the surrounding rocks. These indicate that the magma made room for itself through the means that has been designated by R. A. Daly under the term "overhead stoping." [a] There is no evidence that the mass pushed up or thrust aside the sediments, or that it fused and absorbed any considerable amount of them in the zone exposed to observation. The liquid rock slowly made its way upward by loosening masses above and on either side, which mostly sunk to abysmal depths, though a few were "frozen in" near the contact. The inclusion of Wallace on Ninemile Creek must have sunk for thousands of feet before it was arrested by the increasing vicosity of the cooling magma.

What determined the location of the intrusions is an obscure problem, but the arrangement of the principal areas in a straight line can not be accidental, especially in view of the fact that on Vermilion Creek, near its junction with Clark Fork of Columbia River, in the direct continuation of this line, there is an area of syenite similar to that in the Coeur d'Alene district. This line of intrusion must have been determined by some tectonic cause, yet it is a striking fact that only a few faults—near Delta—and one rather small fold, the Tiger Peak syncline, are even approximately parallel to it. The line is about perpendicular to the average structural trend of the district, but a fact worth noting here is that the line is nearly tangent to the Burke areas south of the main Prichard area. From this line, as has been already pointed out, there is a general dip to the south. Perhaps, then, the row of monzonite masses marks the axis of a great flat anticline formed early in the tectonic history of the region and almost obscured by cross folds superimposed upon it.

### DEFORMATION.

The only direct evidence regarding the chronological relation of the monzonite intrusion to the deformation consists in the fact that the main intrusive is cut by the Dobson Pass fault. This fault in turn is thrown by small dislocations, which have a west-northwesterly direction. From these slight data, however, it is hardly safe to draw the sweeping conclusion that the

[a] The mechanics of igneous intrusion: Am. Jour. Sci., 4th ser., vol. 15, 1903, pp. 269-298; vol. 16, 1903, pp. 107-126.

monzonite was intruded prior to all important deformation, or that of the two greatest fault systems the north-south system as a whole is older than the west-northwest system. Intrusion, here as elsewhere, was probably accompanied by disturbance of the older rocks, and all the faults having a given direction may not be of the same age.

The dynamic phenomena of the Cœur d'Alene district exhibit two features which, although common to many areas of structural deformation, are still in want of any generally accepted explanation. These are, first, the concurrence of normal faults, implying a considerable amount crustal extension, with reversed faults and folds which must in the aggregate have involved a large amount of crustal shortening, the latter effect having in this area far overbalanced the former. The second of these noteworthy features is the presence of reversed faults so steep in dip that it is inconceivable how movement upon them could have been effected by tangential thrust alone without producing a far greater amount of crushing and contortion in the adjacent strata than has been observed.

Perhaps nothing in the literature of faulting affords more helpful suggestions tending toward the explanation of both these features than a recent article by Chamberlin.[a] The basal hypothesis of his discussion is that unbalanced stresses arising from the formation of greatest protuberances of the earth's surface—corresponding to the continental platforms and the major mountain uplifts—result in a glacier-like creep of the surface rocks away from the center of the protuberant mass. The dominant tendency of this action is to produce tension and normal faulting, although locally it may result in compression. The major compression phenomena, however, are ascribed by Chamberlin to collapse of the crust upon a shrinking nucleus, and considered in general as being produced, in any given area, prior to the normal faults. His hypothesis thus appears to offer a rational explanation for the occurrence, side by side, of structural features demanding opposite conditions for their production, by showing how conditions of strong compression and of tension may alternately prevail in one place.

The explanation of faults of extremely low dip, like the Dobson Pass fault, and the remarkable dislocation along the west side of Bitterroot valley which Lindgren[b] has described, appears to be facilitated by Chamberlin's hypothesis, and their existence may help to establish its validity. Lindgren points out that normal faulting on a plane of so low a dip could not be produced by gravity alone, but involves immense horizontal tension. It appears as if this might be supplied by the creep of a very large crust block on the "down-slope" side of the fissure. The rarity of such faults is natural, for it would not often occur that an extensive mass would maintain its integrity long enough to give rise to the requisite accumulation of stretching force.

The special problem of the steep reverse faults is one for which it is perhaps impossible to derive a final solution from a study of the Cœur d'Alene district. It will not be amiss, however, to indicate one or two hypotheses that give some promise of usefulness in this connection. One of these is suggested by Ransome in an article which has done much to stimulate discussion of various aspects of faulting.[c] He calls attention to the evidence that for many faults the movement has a horizontal component in the plane of the fissure, and suggests that the steep reverse faults of the Cœur d'Alene district may possibly be accounted for as the result of such oblique or horizontal movement. The inference which might be drawn from his discussion,[d] that these faults are in reality normal, seems to me to receive no definite confirmation from the observed areal relations, and I do not believe it applicable to all the examples of this type of faulting in the district, although it might serve to explain some of them. The conception of oblique movement goes far, however, to remove the difficulty of imagining the formation of these faults by tangential thrust. The resistance due to friction is a direct function of the angle which the path of a particle involved in the movement makes with the horizon, so that in a given case this friction might prohibit motion directly up the slope of the fault plane, and yet allow motion in an oblique direction.

[a] Chamberlin, T. C., The fault problem: Econ. Geol., vol. 2, no. 7, 1907, pp. 704–724.

[b] A geological reconnaissance across the Bitterroot Range, etc.: Prof. Paper U. S. Geol. Survey No. 27, 1904, pp. 47–51.

[c] Ransome, F. L., The direction of movement and nomenclature of faults: Econ. Geol., vol. 1, 1906, pp. 777–787.

[d] See fig. 65 illustrating article cited.

The possibility that these faults were produced by forces acting in a vertical direction has not yet been considered. It has been suggested in conversation by Mr. A. C. Spencer, and again, in a somewhat more definite manner, by Professor Chamberlin's article. Chamberlin[a] shows that vertical offset between adjacent blocks may result directly from the bulging action, and that "if the fault planes * * * have nearly parallel slopes, no lateral extension is necessarily involved, even in considerable vertical offset." This last condition is fulfilled, in at least some places, in the Cœur d'Alene district, for some of the blocks, as for example that between the Big Creek and Placer Creek faults, are limited on both sides by fissures dipping steeply in the same direction, on one of which the faulting is of the "normal" and on the other of the "reverse" type. Even though this condition were absent, a vertical force acting in a place which was under compressive stress might produce a fault of the kind under discussion. Chamberlin's hypothesis is especially helpful here in that it indicates[b] how as a result of the motion of the shell over the undulatory surface of the subcrustal nucleus, compressive stress might exist locally and temporarily in a region where tension was dominant. While these local compressions would doubtless be quite inadequate to the production of folding so extensive and general as that of the Cœur d'Alene district, they might suffice to compensate the relatively small amount of crustal shortening involved in these faults.

The prevailing dip of cleavage, fissures, and the axial planes of folds to the south and west must have some important significance, and as all these features are presumably produced by lateral pressure we should expect to find their character greatly influenced by the initial conditions under which this force began to act. It is believed that the prevailing attitude of these structural features in this region was determined by gentle inclination of the crust at the beginning of the period of deformation to the north and east. If we suppose a slight initial dip eastward away from the Archean mass, an effort of imagination will make it clear that when strong lateral pressure was exerted there would be a tendency for the ground on the west to override that on the east.[c] Wherever a fold was initiated, the resultant force from the west would be exerted at a higher level than that from the east, and the two would form a mechanical couple whose effect would be to incline the axial plane of the fold toward the east. The fissures were supposedly formed on planes of maximum strain, and these also would dip to the west.

The initial eastward dip is probable on a priori grounds. The rock floor upon which the Algonkian sediments were laid down sagged continuously during the Algonkian era, so that shallow-water conditions were maintained. In a zone situated, as the Cœur d'Alene district probably is, west of that of maximum accumulation, the strata below the uppermost would at any given time have a slight eastward dip, which would reach its maximum in the lowest beds.

Of the existence of an initial northward dip we have no evidence of this sort, for no Archean mass is known to the south. The existence of Algonkian land to the south need not, however, be assumed, for the northward inclination determining the southerly dip of the structural planes might have been produced by crustal warping, followed by intense pressure in a north-south direction. If the character of the north-south folding was determined by initial dip of the strata as laid down, and that of the east-west folds by warping, it will be seen that the north-south folds were probably earlier on the whole than the east-west folds. The same would probably be true of the faults, and so the conclusions arrived at by these speculations are in accord with the evidence of the Dobson Pass fault, thrown by faults of the west-northwest system.

## REGIONAL METAMORPHISM.

The alteration of the muds, marls, and sands of which the Algonkian sediments originally consisted, to compact argillites, limestones, and quartzites, was probably complete long before erosion had brought them into the zone of observation, for the changes involved in the altera-

[a] Op. cit., pp. 707-708.
[b] Op. cit., p. 714.
[c] See Willis, Bailey, Mechanics of Appalachian structure: Thirteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1893, pp. 249-254.

tion are such as take place under great pressure and deep below the surface. The principal alteration of these rocks has consisted in the thorough filling in of original pore spaces with quartz and sericite, and the principal agent in this process was hot circulating water. Gases, however, may have been active in producing tourmaline and some other minerals. The general metamorphism was dependent in large part on dynamic action, for it is most complete where the deformation has been most intense. Force has determined also the orientation of the secondary sericite in planes normal to the direction of pressure.

## DEVELOPMENT OF PRESENT TOPOGRAPHY.

### DETERMINATION OF SUMMIT LEVELS.

The general uniformity of elevation of the high ridges of the Cœur d'Alene Mountains has already been noted. It may be seen by inspection of the map, but it is more forcibly impressed on the mind by views of the field itself, from favorable stations. There are many points from which a number of ridge crests are seen to lie nearly in the same plane. The most suggestive views are probably obtained by looking toward Stevens Peak from the north or west. Seen from a station about 6,000 feet above sea level, the spurs about Stevens Peak have the aspect of remnants of a broad pedestal above which the peak itself rises somewhat abruptly. But these spurs are not exceptional. There are many other similar level crests of which some of the best examples are the divide between Pine and Big creeks, that between Canyon Creek and South Fork of Cœur d'Alene River, and the ridges near Striped Peak. The level tops are not determined by the structure of the rocks, which are strongly tilted, and along much of the Canyon Creek ridge are even vertical. Some hundreds of feet above the level of these crests the higher peaks, of which Kellogg, Stevens, Granite, and Tiger peaks are examples, rise more or less abruptly.

This approximate levelness of ridge tops is general for a large part of the mountainous region of Idaho and Montana. The same condition prevails in all the mountains seen during my reconnaissance of 1905 except the southeast part of the Cabinet Range, and Lindgren[a] observes that it also prevails in the Clearwater Mountains to the south. Lindgren ascribes the origin of this topography to the dissection of an uplifted, nearly level surface or peneplain, and the phenomena in the Cœur d'Alene district already pointed out strongly suggest a similar explanation. In this district, however, the evidence for the former existence of a peneplain is not conclusive. The ridges are narrow, and if a peneplain ever existed, probably none of its actual surface now remains intact. But as an alternative to the peneplain hypothesis, the possibility that a similar topography could be produced by long-continued erosion of a region kept far above the base-level of the streams must not be overlooked.[b]

### FORMATION OF VALLEYS AND TERRACES.

The manner in which the location of the principal streams was originally determined can only be conjectured. The stream courses show no relation to the folds of the rocks and are related to structure only so far as may be explained by the especial rapidity of erosion in the less resistant formations and along fault zones. The intimate relation of certain stream courses to faults has already been pointed out. Its most striking instance is perhaps that of the South Fork of Cœur d'Alene River. Although the present valley floor is only in very small part directly on the Osburn fault, the valley considered as a large feature follows this tectonic line entirely across the district. The middle part of Beaver Creek likewise parallels the Dobson Pass fault in a way that can not be accidental. Though a mile from the main dislocation, it is very probably along a parallel fissure or fissure zone which has weakened the rocks without very greatly displacing them. The course of Prichard Creek from Raven to Murray is also remarkably straight, and parallel to the Thompson Pass fault. The suggestion presents itself at once that the course of the stream is here determined by a fissure having Prichard slates on

[a] Prof. Paper U. S. Geol. Survey No. 27, 1904, p. 59.
[b] See Daly, R. A., Accordance of summit levels among alpine mountains: Jour. Geol., vol. 12, 1904, p. 105.

both sides and therefore not mappable as a fault. Examples might be multiplied to illustrate the fact that the stream courses have to a very large extent been determined by fault lines.

The terraces on the sides of the valley mark halts in the progress of downcutting, during which the energy of the streams was devoted to widening their valleys, and the steep slopes connecting them mark intermediate periods of rapid cutting. The most important group of terraces noted in this district indicates the existence of broad-valley conditions at a period when the streams had reached a depth 800 to 1,000 feet less than their present depth. There are no strictly level benches representing this old valley, which had terraces on its sides representing a still older and broader valley. The remnants of this feature are best seen along the North Fork of Cœur d'Alene River and Beaver Creek, but portions of it still remain in the valley of the South Fork, and in its tributaries there are minor remnants. Of the age of the broad-valley stage we have no definite evidence at present, nor can we make any positive assertion as to its cause. Some conjecture may be hazarded, however, in relation to both these problems.

The most general cause of broad valleys is the attainment by streams of so low a grade that they no longer cut downward, but swing laterally and undermine their banks. Other causes, however, may bring about a cessation in the down-cutting activity of a stream. It may encounter in its lower course a mass of hard rock through which it cuts but slowly, while the upper portion of the stream, cutting down more rapidly in softer rocks, may reach so low a grade as to be able to swing against its banks. Another way in which broad valleys may be formed is by the damning of the stream; for example, by a flow of lava.

It seems possible that the last-named cause was active in this region. The great Miocene lava floods ran up into the valleys of the Cœur d'Alene Mountains, and form terraces upon the slopes about Cœur d'Alene Lake and along the valley of Spokane River, and upon their upper surfaces are stream gravels.

The truth of this conjecture can be proved or disproved only by a careful survey of the valley. If the broad-valley stage could be correlated with the inundation of the basalt it would be fixed as late Miocene or Pliocene. But even though such a correlation may be as yet unjustifiable, the great amount of erosion that has taken place since the broad-valley stage makes it seem probable that these highest terraces were Tertiary.

Later stages in the downcutting of the valley are marked by the lower terraces, but these can not be correlated sufficiently to afford a basis for a detailed account of the later stages of valley cutting.

## GLACIATION.

At a late stage in their physiographic history the Cœur d'Alene Mountains were subjected to alpine glaciation, which has produced characteristic erosion forms and the morainal deposits already described. Typical cirques are found on the northern slopes of all the highest peaks and ridges and many of them contain lakes in rock basins scooped out by the ice. Certain of the higher canyons, also, especially those of Glidden and Canyon creeks, have the U-shaped cross section typical of glaciated valleys.

In addition to the multitude of small glaciers a mile or two in length, there were a few, formed by the confluence of several glaciers, which attained much greater extent. One of these flowed down Canyon Creek nearly to the site of Burke, and has left abundant traces in the form of striæ and morainal deposits, which are found as much as 300 feet above the stream at the mouth of Military Gulch. Glidden Creek also was glaciated down to its junction with Prospect Creek. The greatest glacier of the district, however, was one which occupied the upper part of the St. Regis Valley. It had a depth of at least 700 feet at the mouth of Copper Gulch, and seems from the distribution of its débris to have overflowed at one time through St. Regis Pass into the valley of the South Fork of Cœur d'Alene River.

The glaciation was strictly local in character, and there is no evidence that a continuous ice sheet ever covered the region.

### POSTGLACIAL VALLEY FILLING.

Some of the more extensive areas of valley alluvium, such as those on Eagle and Beaver creeks and the South Fork of Cœur d'Alene River, through which the streams have not yet cut down to bed rock, have been shown by dredging to be of considerable depth. To the west of the district the gravel deposits of the valleys are far more extensive. These thick sheets of gravel could not have been deposited under conditions at all similar to those existing at present, but must have been precipitated from larger and more heavily laden streams than those that now occupy their places. It is believed that they belong to the period of the dwindling of the glaciers, and that they were swollen by the agency of water from the melting ice overladen with morainal débris.

# PART II.—ECONOMIC GEOLOGY.

By Frederick Leslie Ransome.

## CHAPTER I.—INTRODUCTION.

### HISTORY OF MINING DEVELOPMENT.

The story of the opening of the Cœur d'Alene region to mining enterprise goes back to the year 1842, when a mission was established by the Jesuits in the beautiful valley of St. Joseph River, a navigable stream which empties into the head of Cœur d'Alene Lake, about 5 miles south of the embouchure of Cœur d'Alene River. In 1846 the mission was moved to its present site on the latter stream, about 25 miles from the lake, and for many years Father J. Joset and the missionaries associated with him were the only white inhabitants in this whole region. The Cœur d'Alene Indians, about 300 in number, lived chiefly in the vicinity of the mission and in the St. Joseph Valley.

In 1854 Lieut. John Mullan, acting under instructions from the War Department, began explorations for a wagon road over the Cœur d'Alene Mountains, to connect Fort Benton with Fort Walla Walla. These preparations to invade their hunting grounds aroused the hostility of the Indians, who, after defeating a small force under Colonel Steptoe, were subjugated in 1858 by General Wright. In the spring of this year work on the proposed road was begun under a Congressional appropriation, and the task was finished in 1863.[a] The new road, which followed in part an old Hudson Bay trail, crossed from the mouth of St. Joseph River to the mission on the Cœur d'Alene. Thence it ascended the main stream and South Fork to a point about 3 miles east of the present town of Mullan. Here it turned southward, crossed the divide through the Sohon or St. Regis Pass, and continued down St. Regis River, following the route later taken by the railroad to Missoula. The length of this road was 624 miles and the cost $230,000.

Roughly constructed as it was, this highway, now familiarly known as the "old Mullan road," was for many years the only line of travel into the region to whose early development it substantially contributed. It traversed what afterwards proved to be the most productive part of the district, but the discovery of the lead-silver deposits was reserved for a later date. The section of the old road that crosses the divide east of Mullan is still in occasional use and is shown on the accompanying topographic map (Pl. I, in pocket).

The first prospecting in the region appears to have been done by Thomas Irwin, who in 1878 located a quartz claim near the Mullan road, apparently in or near Gold Run Gulch. In the summer of 1879 a party including A. J. Prichard, moving northward from the Mullan road over the Evolution trail, discovered Prichard Creek. In 1882 Gillett, another member of the party, found placer gold and located a claim on Prichard Creek. Prichard, who had meanwhile left the district to report on its resources, returned in 1883 with documents giving him power of attorney to act for his friends, and staked out a great number of claims, including the afterward well-known Widow claim at Murray. This procedure led to protracted litigation and to much bitter feeling. The first quartz claim on Prichard Creek was the Paymaster, near Littlefield, located by Patrick Flynn on September 21, 1883.

[a] Mullan, Capt. John, U. S. A., Report on the construction of a military road from Fort Walla Walla to Fort Benton, Washington, 1863; Miners and travelers' guide to Oregon, Washington, Idaho, etc., New York, 1865.

The discoveries of Prichard and Gillett were followed by a general rush to the North Fork country early in 1884, and in May, Eagle, at the junction of Eagle and Prichard creeks, had become a bustling town connected by trail and telegraph with Belknap, 32 miles away, on the Northern Pacific Railway. It was soon found, however, that the richest placers lay higher up Prichard Creek, particularly in Dream, Buckskin, and Alder gulches, and the center of population soon shifted to the new town of Murray.

In May, 1884, Mr. Adam Aulbach arrived in Belknap with the intention of starting a newspaper at Eagle, but, being unable to get his press and fonts over the miry trail, he opened an office at Belknap and began the publication of the "Belknap Sun." He soon afterwards moved to Murray, where in 1904 he was still publishing his paper as the "Cœur d'Alene Sun." The early files of this newspaper contain much interesting information, evidently collected with uncommon care and ability, and have furnished much material for the present sketch.

The placer claims were 20 acres in extent and some of them were very rich. One of the most prominent was the Widow, on the eastern edge of the town of Murray. Other well-known placer claims were the Gillett, half a mile below Murray, and the Myrtle, in Trail Gulch. Probably the richest placers in the district, however, were those of Dream Gulch. The gold was usually coarse, nuggets up to 33 ounces in weight having been found in Buckskin Gulch and up to 29 ounces on Trail Creek, while several large nuggets were obtained from time to time in Dream Gulch.

Although the chief excitement at this time centered in the rich gold placers near Murray, the lead-silver veins of the South Fork were beginning to attract attention. In 1884 Col. W. R. Wallace had a cabin and store in the dense grove of cedars that covered the future site of the town now bearing his name. His settlement was then known as Placer Center. One of Wallace's mining claims was the Ore-or-no-go, now part of the Hecla mine at Burke. Another was near the site of the present town of Mullan. At the same time Mr. W. B. Heyburn (now United States Senator from Idaho) began work on the Polaris mine in Polaris Gulch. The Tiger claim on Canyon Creek was also located in 1884 by John Carton and Almeda Seymour, who bonded it to John M. Burke. In 1885 the Tiger mine, in spite of its comparatively inaccessible position, had been opened by three tunnels and had about 3,000 tons of lead-silver ore on the dump. It was bought in this year by S. S. Glidden for $35,000, Burke and Carton retaining contingent interests. Other mines located in 1884 were the Gold Hunter, Morning, and You Like near Mullan and the Black Bear, San Francisco, and Gem of the Mountains (now comprised in the Helena-Frisco mine) near Gem.

In 1885 Murray, with a population of about 1,500, became the seat of Shoshone County. In spite of the promising character of the lead-silver deposits on the South Fork of the Cœur d'Alene, the gold placers on Prichard and Beaver creeks were still the center of attraction, and considerable work was being done on the auriferous quartz veins between Murray and Littlefield. The Golden Chest mine had a 20-stamp mill and employed from 25 to 30 men. The Mother Lode, Occident, Treasure Box, and other quartz mines on the south side of Prichard Creek, between Murray and Ophir Gulch, worked their gold ores in arrastres which were operated at a profit for several years. A very rich pocket of free gold in quartz was worked for several years on the Buckeye Boy claim in Dream Gulch.

Communication with the mines on the South Fork was at this time difficult. Small steamers plying across the lake ascended Cœur d'Alene River to the mission, where passengers and freight were transferred to wagons or horses and carried over the rough Mullan road, then much out of repair. Murray was connected by a poor road with Thompson Falls, on the Northern Pacific Railway, by a road down the North Fork with the mission, and by road with Delta. Practically the only route from the county seat to the South Fork was by way of the Evolution trail, Evolution being a little settlement about 2 miles west of Osburn's ranch which was then a well-known stopping point for travelers. It was impossible to mine and ship lead ores until better facilities for transportation were obtained.

The discovery of the Bunker Hill mine by "Phil" O'Rourke and N. S. Kellogg in 1885, and of the Sullivan mine by "Con" Sullivan and Jacob Goetz and the evident existence of large bodies of rich ore in the Tiger, Poorman, Granite, San Francisco, Morning, and other mines removed all doubts of the future importance of the South Fork mines. The opening of the year 1886 saw a decided rush from the outside and from the waning placers of Murray into this new field, particularly to the settlements of Milo and Kentucky, now parts of Wardner and Kellogg. Triweekly stages ran from Mission to Wardner and a stage road was built connecting Delta with the South Fork.

In 1886 ore from the Bunker Hill and Sullivan mines was hauled by wagons to Mission, carried by boat to the outlet of the lake, and thence shipped to Helena, Mont. The ore from the Last Chance, Tyler, and Sierra Nevada mines was treated in a new smelter at Milo. This early attempt at local smelting was, however, soon abandoned.

In the following year a narrow-gage railroad was completed by the Cœur d'Alene Railway and Navigation Company from Mission to Wardner Junction, at the mouth of Milo Creek. Wardner had now become a town of 1,500 people, while the population of Murray had fallen to about 1,000. There were about 500 inhabitants at Wallace, and Burke and Mullan were growing settlements. Probably 100,000 tons of ore was piled on the dumps of the Canyon Creek mines awaiting means of transportation. The narrow-gage road had now reached Osburn, while the Oregon Railway and Navigation Company and the Northern Pacific Railway were both striving to secure entrance to the district. Freight rates on concentrates, in 1888, were from $5.50 to $6 a ton by narrow-gage railway and by boat to Cœur d'Alene City. From that point the rates were $8 to Helena, $10.40 to Portland, $17 to Omaha, and $18 to Denver.

In April, 1887, the Bunker Hill and Sullivan mines were sold to S. G. Reed and in August the Bunker Hill and Sullivan Mining and Concentrating Company was organized with a capital of $3,000,000. The Poorman, Granite, and Morning mines were also sold at about this time. The completion of the narrow-gage railway to Burke in this year enabled the Canyon Creek mines to ship their ore. Probably over 50,000 tons of lead-silver ore was mined in 1887, the principal producers being the Tiger, Bunker Hill and Sullivan, Tyler and Stemwinder, Last Chance, Sierra Nevada, Poorman, and Granite. The Mammoth and Standard veins were as yet merely good prospects. The ore of the Sierra Nevada was chiefly carbonate, carrying 47 per cent lead and 60 to 90 ounces of silver to the ton. Freight to Portland was $16 a ton, and the cost of mining and treating ore of an average value of $96 was $48.85 a ton.

In 1888 placer mining near Murray and Delta had greatly declined. A pipe line was constructed from Raven in 1890 to hydraulic the bench gravels of the so-called Old Wash near Murray, and some hydraulic mining is still occasionally carried on in Dream Gulch. A hydraulic elevator was operated for some time in the bed of Prichard Creek about a mile below Murray, and some dredges were working near Delta in 1904. But the scene of activity had definitely shifted by the year 1888 to the lead-silver mines of the South Fork.

The principal events in 1890 were the completion into the district of the tracks of the Northern Pacific Railway and Oregon Railway and Navigation Company, the partial destruction by fire of Wallace and Wardner, and the shipment of rich ore ($89 in silver and 55 per cent of lead to the ton) from the Mammoth mine. The old narrow-gage line was absorbed by the Oregon Railway and Navigation Company and its tracks were replaced by those of standard gage. Most of the larger mines were by this time equipped with concentrating mills, the largest being the Bunker Hill and Sullivan, which was completed in 1891 and had a capacity of 500 tons a day.

In 1891 the Morning mine was sold for $400,000. About $200,000 in gold was produced this year, chiefly from the Golden Chest, Golden King, Mother Lode, Occident, Treasure Box, and Buckeye Boy quartz mines, near Murray.

At the beginning of 1892 most of the South Fork mines stopped work, ostensibly to secure a reduction in freight rates, which then ranged from $6 a ton on second-class concentrates (less than 40 per cent lead) to Helena, to $16 on first-class concentrates to Omaha. The mills at this time concentrated about 5 to 1 and saved about 75 per cent. The cost of mining ranged from $2.50 to $4.50 a ton. Smelting charges ranged from $9 to $12 a ton, most of the ore going to Denver and Omaha. The total cost of mining, freight, and treatment was from

$25 to $28 a ton. Wages were $3.50 a day. In the following April a reduction was made in wages, followed by a strike of the union men. The Frisco, Gem, and Bunker Hill and Sullivan mines attempted to resume work with nonunion men, and in July the Frisco and Gem mines were attacked by armed strikers. After one of the buildings had been blown up with dynamite, which was slid down the penstock to the mill, the nonunion men surrendered. The Bunker Hill and Sullivan mine was next attacked, and in order to prevent the destruction of the mill the mine manager agreed to discharge his nonunion force. The nonunion men from these mines were deported from the district and when about to embark at Mission were fired on and some of their number were killed. Troops were called into the district and for a time order was partially restored.

The trouble, however, was not over. In July, 1894, a second attack was made on the Gem mine, and a nonunion man was murdered. In this year also the miners' unions celebrated the second anniversary of the first attack on the Gem mine with parades, speeches, and decoration of the graves of the union men killed in that affair. This remarkable celebration, in which women and children took part, is said to have called forth more general and enthusiastic participation than the observance of the Fourth of July. In December the Bunker Hill and Sullivan mine closed rather than accede to union demands. In June, 1895, it resumed partial operations, paying $3 a day to miners and $2.50 to muckers and surface men. The Tiger and Poorman mines consolidated in this year.

In 1896 the Tiger-Poorman mine attained a depth of 1,100 feet and the Campbell tunnel of the Standard mine, 2,600 feet in length, reached the Standard-Mammoth ore body. During the following year the Canyon Creek mines continued active in spite of labor troubles. The Tiger-Poorman mine was producing about 400 tons of ore daily and completed a new concentrating mill.

In May, 1898, the Empire State Mining and Development Company was organized to control the Last Chance mine and to acquire additional territory west of Milo Gulch. This was the beginning of the process of consolidation that afterward resulted in the formation of the Federal Mining and Smelting Company. The county seat was this year moved from Murray to Wallace, now the largest town in the district.

The opening of the year 1899 found the miners' unions still determined to enforce their demands on the mine owners and in a particularly bitter mood against the Bunker Hill and Sullivan company, which maintained its right to employ nonunion labor. On April 29 a force of several hundred men took possession of the regular passenger train at Burke and ran it down to Gem, where they broke open the magazine of the Helena-Frisco mine, and having obtained about 3,000 pounds of dynamite proceeded to Kellogg, gathering recruits en route. Reaching that point in mid-day the armed body advanced on the mill and office of the Bunker Hill and Sullivan mine, shooting down some men met on the way. Resistance to such a force was out of the question. The office of the company was rifled and both office and mill were totally destroyed by dynamite.

After this outbreak, 500 regular troops were sent into the district and martial law was proclaimed. The mines were closed until June, when the Standard mine reopened with men brought from Missouri. The other mines resumed work one by one as they secured nonunion miners. From that time to the present employment in the larger mines (with one exception) has been procurable solely through a bureau maintained by the principal mine owners.

In 1901 the Tiger-Poorman mine, previously acquired by the Buffalo Hump Mining Company, was consolidated with the holdings of the Empire State Company and in September, 1903, the Empire State, Standard, and Mammoth properties were all consolidated as the Federal Mining and Smelting Company. Other notable events of the past few years were the opening in 1901 of the rich ore body of the Hercules mine, which produced ore of a gross value of about $2,000,000 in less than three years from its discovery, and the development of the Snowstorm mine in 1903. The latter is the only mine in the district that ships copper ore. Near the end of 1905 the Morning mine was purchased by the Federal Mining and Smelting Company, the reported price being $3,000,000.

## PRODUCTION.

### LEAD, SILVER, AND GOLD.

For several years Cœur d'Alene has been the leading lead-producing district in the United States. Out of a total of about 280,000 short tons of lead produced by the mines of this country in 1903, over 100,000 tons, or rather more than one-third, came from the Cœur d'Alene district. This considerably exceeded the combined product of Missouri, Kansas, Iowa, Illinois, Wisconsin, and Kentucky for that year, and was about double the production of Utah or Colorado. In 1905, out of a total production for the country of about 302,000 tons,[a] the Cœur d'Alene district supplied nearly 124,000 tons.

The output of Shoshone County, which is practically that of the Cœur d'Alene district, from the beginning of mining to the end of 1905, is shown in the following table. The gold there accounted for is derived entirely from the placers and gold-quartz veins near Murray, the lead-silver ores containing so little gold that the quantity is negligible. The silver tabulated is that obtained by smelting the lead-silver ores, no record being kept of the small amount of silver occurring with the Murray gold. The figures for the production of the precious metals, except where otherwise indicated, are taken from the reports of the Director of the Mint. Those for lead are derived partly from the same source, where the lead output for certain years is given with that of silver, and partly from the volumes of "Mineral Industry." The amounts in the columns of values are calculated in accordance with the average commercial value of lead (New York quotations) and silver for each year and the value ($20.67) of a fine ounce of gold. In settlement with the miners, an allowance of 10 per cent of lead and from 2 to 5 per cent of silver is usually made for so-called loss in smelting. So far as could be determined the gross values given in the table are based on the assay return, less this deduction. It is impossible, however, to obtain absolute uniformity in the figures. The shippers usually receive for their lead 90 per cent of the current New York quotation, after deduction of 10 per cent from the assay value. When the New York quotation exceeds $4.10 per hundred pounds, the discount is somewhat increased. Freight and treatment charges range from $16 to $20 per ton for concentrates, with lower rates for some crude ore.

*Production of lead, silver, and gold in the Cœur d'Alene district from 1884 to 1905.*

| Year. | Lead. | | Silver. | | Gold. | | Value of total metallic product. | Ratio of silver to lead by weight. | Ounces of silver to each unit of lead.[b] |
|---|---|---|---|---|---|---|---|---|---|
| | Tons of 2,000 pounds. | Value. | Fine ounces. | Value. | Fine ounces. | Value. | | | |
| 1884 | | | | | 12,500 | $258,375 | $258,375 | | |
| 1885 | | | | | 18,220 | 376,607 | 376,607 | | |
| 1886 | [c]1,500 | $138,300 | 116,246 | $115,664 | 8,823 | 182,371 | 436,335 | 1 : 384 | 0.77 |
| 1887 | [c]5,980 | 538,200 | 340,000 | 332,520 | 7,367 | 152,276 | 1,022,996 | 1 : 515 | .56 |
| 1888 | [c]8,000 | 705,600 | 554,000 | 520,760 | 10,250 | 211,867 | 1,438,227 | 1 : 422 | .69 |
| 1889 | [c]17,500 | 1,333,500 | 1,095,265 | 1,025,168 | 8,433 | 174,310 | 2,532,978 | 1 : 466 | .62 |
| 1890 | [c]27,500 | 2,392,500 | 1,499,663 | 1,574,646 | 8,000 | 165,360 | 4,132,506 | 1 : 531 | .54 |
| 1891 | [c]33,000 | 2,857,800 | 1,825,765 | 1,803,856 | 10,000 | 206,700 | 4,868,356 | 1 : 626 | .55 |
| 1892 | [d]27,839 | 2,266,094 | 1,195,904 | 1,045,220 | 11,000 | 227,370 | 3,538,684 | 1 : 679 | .42 |
| 1893 | [d]29,563 | 2,424,166 | 1,963,561 | 1,529,614 | 14,748 | 304,841 | 4,258,621 | 1 : 440 | .66 |
| 1894 | [d]30,000 | 1,968,000 | 2,343,314 | 1,485,661 | 17,531 | 362,365 | 3,816,026 | 1 : 373 | .78 |
| 1895 | [d]31,000 | 2,008,800 | 2,471,300 | 1,626,115 | 18,439 | 381,134 | 4,016,049 | 1 : 366 | .79 |
| 1896 | [e]37,250 | 2,212,650 | 3,163,657 | 2,132,304 | 17,369 | 359,017 | 4,703,971 | 1 : 343 | .84 |
| 1897 | [e]57,777 | 4,159,944 | 3,756,212 | 2,264,996 | 16,404 | 339,070 | 6,764,010 | 1 : 448 | .65 |
| 1898 | [e]56,339 | 4,225,425 | 3,521,982 | 2,070,925 | 13,011 | 268,937 | 6,565,287 | 1 : 466 | .62 |
| 1899 | [e]50,006 | 4,440,533 | 2,737,218 | 1,645,068 | 8,602 | 177,803 | 6,263,404 | 1 : 533 | .54 |
| 1900 | [e]81,535 | 7,207,694 | 5,261,417 | 3,262,078 | 5,754 | 118,935 | 10,588,707 | 1 : 452 | .64 |
| 1901 | [e]68,953 | 6,026,492 | 4,339,296 | 2,603,577 | 4,915 | 101,593 | 8,731,662 | 1 : 463 | .62 |
| 1902 | [e]74,739 | 6,091,228 | 5,033,928 | 2,657,914 | 4,761 | 98,410 | 8,847,552 | 1 : 433 | .67 |
| 1903 | [c]103,691 | 8,772,258 | 5,471,620 | 2,954,674 | 7,651 | 158,146 | 11,885,078 | 1 : 552 | .52 |
| 1904 | [f]107,561 | 9,271,672 | [f]6,141,426 | 3,512,895 | [g]2,226 | 46,015 | 12,830,582 | 1 : 511 | .57 |
| 1905 | [h]123,830 | 11,640,020 | [h]6,690,000 | 4,080,900 | [g]1,886 | 38,987 | 15,759,907 | 1 : 540 | .54 |
| Total and average | 973,563 | 80,680,876 | 59,521,774 | 38,244,555 | 227,890 | 4,710,489 | 123,635,920 | 1 : 477 | .62 |

[a] Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906, p. 364.
[b] A unit of lead is 1 per cent to the ton of ore or 20 pounds.
[c] Reports of the Director of the Mint on the production of precious metals.
[d] Estimated.
[e] The Mineral Industry: its statistics, technology, and trade in the United States and other countries, New York.
[f] Reported by S. A. Easton to Eng. and Min. Jour., January 5, 1905.
[g] Mineral resources U. S. for 1905, U. S. Geol. Survey, 1906, p. 239.
[h] Reported by S. A. Easton to Eng. and Min. Jour., January 6, 1906.

The following table, which is based on the statements made by the mining companies to the assessor of Shoshone County, gives a comprehensive view of the operation of the lead-silver mines in 1905 and 1906. In this table the value of the lead is presumably calculated from the selling price, which averaged about 4.1 cents per pound in 1905 and 4.4 cents per pound in 1906.

*Production and profits from lead-silver mines of Cœur d' Alene district for 1905 and 1906.*

| Mines. | Short tons of ore or concentrates shipped. | | Gross value of ore or concentrates. | | Net profits. | |
|---|---|---|---|---|---|---|
| | 1905. | 1906. | 1905. | 1906. | 1905. | 1906. |
| Federal group: | | | | | | |
| Mace mines | 353,408 | 334,403 | $2,694,824 | $3,969,941 | | $1,912,576 |
| Wardner mines | 176,869 | 168,608 | 1,406,440 | 1,473,512 | $1,565,218 | 436,961 |
| Burke mines | 132,051 | 117,476 | 535,813 | 680,875 | | 80,439 |
| Morning | 241,676 | 313,070 | 1,325,308 | 1,651,441 | | 255,238 |
| Bunker Hill and Sullivan | 342,414 | 338,879 | 4,586,113 | 4,771,748 | 1,957,477 | 2,264,389 |
| Hercules | 11,422 | 17,712 | 943,307 | 1,550,225 | 375,349 | 787,534 |
| Hecla | 97,366 | 106,260 | 871,449 | 1,249,680 | 363,125 | 555,296 |
| Gold Hunter [a] | 41,634 | 41,357 | 143,207 | 221,556 | | |
| Helena-Frisco [a] | 1,125 | 775 | 64,457 | 59,709 | | |
| Tamarack and Chesapeake [a] | | 323 | | 19,589 | | |
| Cœur d'Alene Development Co. [a] | 75 | | 3,204 | | | |
| | 1,396,040 | 1,438,863 | 12,574,122 | 15,648,276 | 4,261,169 | 6,292,433 |

[a] Operated at a loss.

## COPPER.

The output of copper for the years 1905 and 1906, as furnished by statements from the Snowstorm mine to the county assessor, was as follows:

*Production of copper in Cœur d' Alene district, 1905–6.*

| Year. | Tons of ore extracted. | Gross value. | Net profit. |
|---|---|---|---|
| 1905 | 65,000 | $834,825 | $245,267 |
| 1906 | 82,679 | 1,069,324 | 144,322 |

The gross output for 1906 was 6,233,940 pounds of copper.

## ZINC.

Prior to 1905 no zinc ore was produced in the Cœur d'Alene district. In that year, however, the Success Mining Company built a mill of 150 tons capacity at the Granite mine and began concentrating sphaleritic ore. In 1906, according to Mr. J. M. Boutwell,[a] this mill, working an ore carrying from 20 to 25 per cent of zinc, was turning out from its jigs a "middling" carrying 45 per cent of zinc. The Sixteen-to-One mine also produced considerable zinc in 1906.

In 1906 a little zinc blende was sorted from the Hercules ore and shipped. Preparations were made this year also to concentrate and save the sphalerite in the Helena-Frisco ore.

On Pine Creek, southwest of Wardner, are a number of prospects which have of late attracted attention as possible sources of zinc ore. Among them may be mentioned the Highland Chief, Douglas, Nabob, and Surprise. All the Pine Creek ores contain zinc and it is probable that this feature, formerly regarded as detrimental, may turn some of these prospects into profitable mines. Some of the Pine Creek ores are said to contain as much as 30 per cent of zinc.

The zinc output for the district amounted to 2,054,998 pounds in 1906.

[a] Oral communication.

## GENERAL CHARACTER AND DISTRIBUTION OF THE ORE DEPOSITS.

The mineral resources of the Cœur d'Alene district, in the order of their present importance, are (1) lead-silver ores, (2) copper ores, and (3) gold ores. The general distribution of these ores is shown in fig. 3.

The lead-silver ores come principally from metasomatic fissure veins which traverse the siliceous formations of the sedimentary series of the Cœur d'Alene. The deposits are lodes which have been formed chiefly by the replacement of quartzite, or allied rocks, by galena and siderite along zones of fissuring. They occur mainly in the Revett and Burke formations, but are found to a less extent in the Prichard, St. Regis, and Wallace. They occupy two important

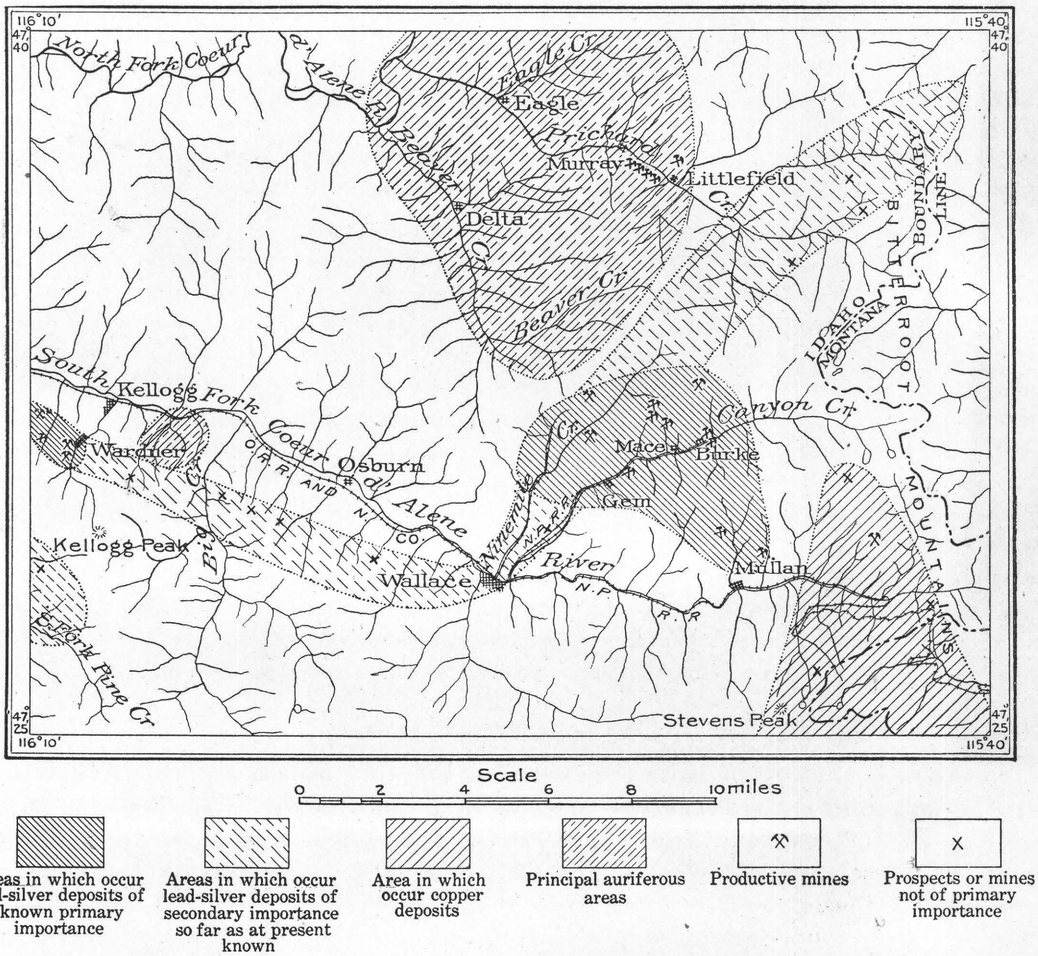



FIG. 3.—Map showing general distribution of the different kinds of ore in the Cœur d'Alene district. The boundaries of these areas are obviously indefinite and the lines drawn do not correspond to any sharp natural division between productive and barren territory.

areas or belts, both of which are in the southern half of the district, in the drainage basin of the South Fork of Cœur d'Alene River. One belt stretches from South Fork near Mullan northwestward to Dobson Pass, at the head of Ninemile Creek. The other extends from Wardner beyond the western boundary of the mapped area.

The deposits belonging to the larger, eastern belt are conveniently divisible into three groups—(1) the Mullan lodes, including those of Mill Creek and Hunter Gulch near Mullan; (2) the Canyon Creek lodes, including those near the towns of Burke, Mace, and Gem; and (3) the Ninemile Creek lodes, lying northwest of the crest of the narrow ridge that extends from Wallace to Tiger Peak. The Canyon Creek deposits are the most productive, followed by the Wardner and Mullan groups. These three groups produce over 98 per cent of the lead and silver coming from the district.

Outside of the two productive areas the district contains many deposits of lead-silver ore that are small or have never been thoroughly developed. Between Wallace and Wardner are several veins in what is colloquially referred to as the "dry belt." These are in the Wallace and St. Regis formations, and though some, like the Polaris, were among the first locations in the district and have produced rich ore they have not proved profitable on the whole. Attention has recently been directed to lead-silver prospects in the Prichard slates of the Murray area. Although no paying lead-silver mine has yet been opened in these slates, the work accomplished in 1904 showed that some of the lodes in the arenaceous upper beds of this formation contain encouraging quantities of ore, and some shipments have since been made.

The lead-silver deposits do not as a rule outcrop continuously or conspicuously and as the country is thickly clothed with forest and undergrowth it is not surprising that the ores were not sooner discovered. Although galena came to the surface on the Bunker Hill claim, the course of the deposit was not at first apparent and most of the claims near Wardner were laid out across the line of the Bunker Hill fissure with which the ore bodies were afterwards found to be associated. This fact and the peculiar form of the Wardner deposits as a whole has been productive of long-continued litigation between the two principal companies operating in this part of the district.

The gold deposits, which, as shown in the section on production and in the historical sketch of the district, were formerly more productive than at present, are chiefly in the northern part of the district, in the drainage basin of the North Fork of Cœur d'Alene River. They comprise gold-quartz veins, bench gravels lying from 250 to 300 feet above the present streams and recent stream gravels. The veins, so far as known, occur only in the Prichard slate and are usually of the type known as bed veins—that is, they follow the planes of stratification. The principal gold-bearing veins are near the town of Murray on Prichard Creek. The greater part of the placer gold has been obtained from the streams flowing into Prichard Creek and from the eastern tributaries of Beaver Creek which head in the large area of Prichard slate north of Dobson Pass.

Copper in small quantities has been found in a few prospects in the southeastern part of the district. The only deposit, however, that has been worked on a commercial scale is that of the recently opened Snowstorm mine, 3 miles east-southeast of Mullan. This is an impregnated zone following certain bedding planes in the Revett quartzite.

## MINES AND MINING.

The principal companies operating in the Cœur d'Alene district on lead-silver ores are the Federal Mining and Smelting Company, with an authorized capital of $30,000,000, owning the Tiger-Poorman mine at Burke, the Standard-Mammoth mine at Mace, and the Last Chance mine at Wardner;[a] the Bunker Hill and Sullivan Mining and Concentrating Company, capitalized at $3,000,000, and owning the Bunker Hill and Sullivan mine at Wardner; Larson & Greenough, owning the Morning mine[b] near Mullan; the Hercules Mining Company, owning the Hercules mine; and the Hecla Mining Company, capitalized at $250,000, and owning the Hecla mine, both near Burke. Other mines which have contributed largely to the general production in the past, although they are not at present being worked on the same profitable scale as those just mentioned, are the Helena-Frisco mine, near Gem; the Granite and Custer mines, on the west slope of Tiger Peak; the Gold Hunter mine, near Mullan; the Sierra Nevada mine, about a mile west of Wardner; and the Crown Point, owned by the Cœur d'Alene Development Company, also west of Wardner, but just outside of the area mapped. The location of other properties not here mentioned may be found from the accompanying claim map (Pl. VIII), published through the courtesy of Messrs. C. F. O. and R. S. Merriam, of Wallace.

[a] These different mines are officially designated by the company as the Burke mines, the Mace mines, and the Wardner mines. It is less confusing to the reader, however, inasmuch as there are other mines at Burke and Wardner not owned by this company, to retain the old familiar names by which the mines are still known by everyone in the district.

[b] Since this was written the Morning mine has been sold to the Federal Mining and Smelting Company.

Some idea of the relative importance of the different mines may be had from the following figures, furnished to the assessor of Shoshone County. Those for 1903 indicate the productive rank of the mines when field work in the district was begun and are shown for comparison with the latest data.

*Gross value of product from lead-silver mines of the Cœur d'Alene district in 1903 and 1906.*

| | 1903. | 1906. | | 1903. | 1906. |
|---|---|---|---|---|---|
| Bunker Hill and Sullivan | $1,604,538 | $4,771,748 | Hecla | $655,721 | $1,249,680 |
| Standard-Mammoth | 2,544,918 | 3,969,941 | Tiger-Poorman | 580,477 | 680,875 |
| Morning | 1,635,612 | 1,651,441 | Gold Hunter | 166,000 | 221,556 |
| Hercules | 850,258 | 1,550,225 | Helena-Frisco | 465,287 | 59,709 |
| Last Chance | 1,409,672 | 1,473,512 | | | |

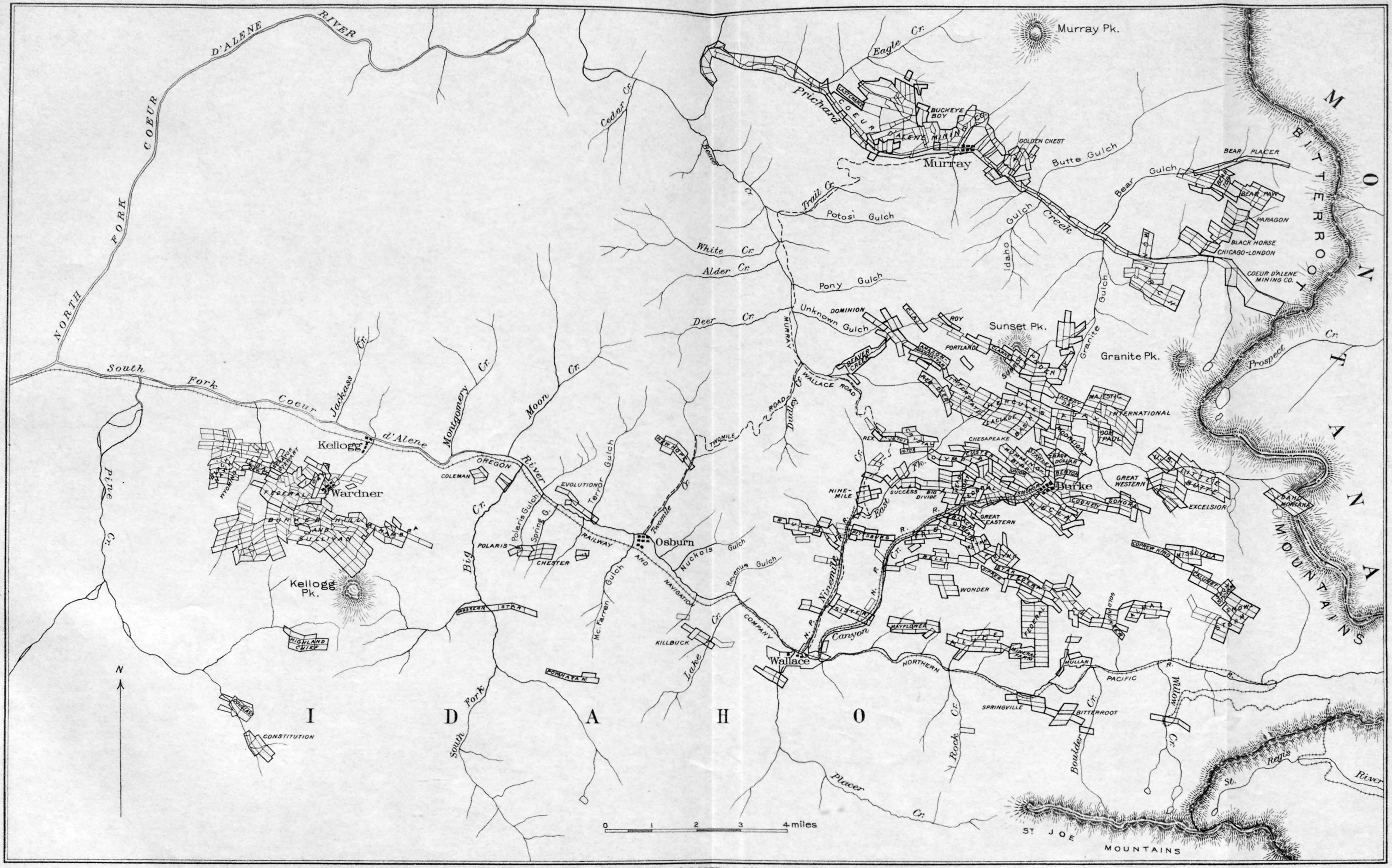
The Bunker Hill and Sullivan and Last Chance mines are on the same general zone of fissuring and their workings, as shown in Pl. XIX (p. 156), connect at several points. The deepest level on this Wardner group at the time of visit was the Kellogg tunnel of the Bunker Hill and Sullivan mine. This tunnel, which is a crosscut, runs southward from the mill, situated on the South Fork about a mile west of Kellogg, for a distance of about 12,000 feet to the lode. It cuts the latter about 2,000 feet below the croppings. Two levels have since been opened below this tunnel. The Morning mine has a crosscut adit 2 miles north of Mullan, the ore in 1904 being brought down to the mill on the South Fork over a narrow-gage railway. A new adit, then being run from the mill, has since cut the lodes about 1,000 feet below the former main level. The Gold Hunter mine is also opened by a crosscut adit, from which two lower levels are worked through a winze. The Tiger-Poorman and Hecla mines are operated through shafts in the town of Burke. These workings are respectively 1,950 and 900 feet deep. The Standard-Mammoth mine has two long crosscut adits, the Campbell tunnel, running nearly north from a point on Canyon Creek just below Mace, and the No. 6 tunnel, running nearly northeast from a point on the creek 3,000 feet west and about 150 feet below the Campbell adit. From the end of the Campbell tunnel, an underground shaft or winze gives access to five levels, the lowest in 1904 being 1,050 feet below the adit level, or about 2,000 feet below the apex of the vein. The main adit of the Helena-Frisco mine is a south crosscut from Canyon Creek near Gem, at the end of which is a shaft 1,400 feet deep, connecting with seven levels. The main adit of the Hercules mine is on Tiger Peak, about 1½ miles north of Burke and about 1,500 feet above the bed of Canyon Creek. This mine at the time of visit produced no concentrates, the crude ore being hauled by wagons to the railroads at Burke. A mill, however, has since been erected.

It appears from the foregoing notes that the mines working below the main canyon bottoms of the district are the Tiger-Poorman, Hecla, Standard-Mammoth, and Helena-Frisco. (See Pl. XIV, p. 130.) Of these, the Tiger-Poorman, 1,950 feet, is the deepest. J. R. Finlay[a] who has given an excellent account of mining methods employed in the Cœur d'Alene district, estimates that at least 70 per cent of the ore extracted has been taken out through adits, without hoisting or pumping, and of the remaining 30 per cent, at least two-fifths has been run out through adits from underground shafts. The Tiger-Poorman and Hecla are the only important mines in which the ore is hoisted directly to the surface through shafts. All the large mines work by back stoping and the stopes are elaborately timbered.

About 3,000 men were engaged in working in the mines and mills in 1906. At the present time all the prominent companies, with one exception, engage their men through a central employment bureau maintained by the employers. The wages paid in the principal mines in 1904 were as follows:

| | | | |
|---|---|---|---|
| Foreman | $6.00 to $7.00 | Blacksmiths | $4.00 |
| Locomotive engineers (Morning mine) | 6.00 | Timbermen | 3.75 to 4.00 |
| Shift bosses | 4.00 to 6.00 | Miners, machine men, muckers, mill men, and blacksmith's helpers | 3.50 |
| Head blacksmiths | 4.50 | Yardmen | 3.00 |
| Hoisting engineers | 4.00 | | |

[a] The mining industry of the Cœur d'Alenes, Idaho: Trans. Am. Inst. Min. Eng., vol. 33, 1903, pp. 235-271.




## CLAIM MAP OF THE COEUR D'ALENE DISTRICT

Simplified and reduced from a map by C. F. O. and R. S. Merriam

These wages, all things considered, are undeniably good; for the district is readily acces sible, has a moderate altitude, and an almost ideal climate. The mines, moreover, have convenient adits and are well equipped and well ventilated. The cost of living, compared with other mining districts in the Rocky Mountains, is moderate.

The district is abundantly supplied with water, very little of which is allowed to run to waste. The Bunker Hill and Sullivan, Morning, Gold Hunter, Hecla, Mammoth, and Standard mills are run by water power for at least part of the year, usually by Pelton wheels under heads up to 900 feet. Water power is also utilized to a considerable extent for compressing air, the Morning mine having a 100-drill Rix compressor driven by Pelton wheels under heads of 1,200 and 1,500 feet. The Hecla mill and the pumps in the Tiger-Poorman mine are usually run by electricity locally generated by water power.

Recently electric power, generated at the falls in Spokane, has been brought into the district and is used in running the Tiger-Poorman and Last Chance mills, a 40-drill compressor at the Morning mine, and other machinery. The length of the line from Burke or Mullan to Spokane is about 100 miles. In 1903 this line was carrying 45,000 volts and furnishing about 1,600 horsepower.[a] The cost of this power at the mines is $50 per annum for each horsepower. This is cheaper than steam, though the latter is used for hoisting at the Tiger-Poorman and Standard-Mammoth mines.

All the large mines require much timbering and probably few mining regions are better supplied than the Cœur d'Alene district with abundant and cheap material suitable for this purpose. A large part of the timber used is derived from the vicinity of Cœur d'Alene Lake. Some is cut in the southeastern corner of the district, and the Hercules mine has its own timber land and sawmill on the north side of Tiger Peak.

Pumping is not a serious item except at the Tiger-Poorman mine, where the quantity of water to be handled ranges from 500 to 1,000 gallons a minute, according to the time of year. Two Nordberg pumps, each with a capacity of 500 gallons per minute, are installed on the 1,600-foot level and raise the water in one lift to the surface. Electricity, generated by local water power, is used for pumping, with steam as a reserve.

The only copper mine in the district is the Snowstorm, about 3½ miles east of Mullan. It was worked under lease in 1904, but has since been purchased by T. L. Greenough and others and is becoming increasingly productive. The ore body is reached by tunnels high above the valley of the South Fork.

Practically no gold-quartz mining was in progress in 1904. The principal mines are just east of Murray and are developed almost entirely by adits. The Golden Chest has the most extensive workings, but all are small mines.

## MILLING.

A very small proportion of the lead-silver ores are shipped as they come from the mine. The bulk of the material is concentrated to a product containing about 50 per cent of lead. The ore undergoes a first crushing by breakers and rolls and is subjected to a preliminary sizing by trommels. The coarser particles are then distributed to various sets of Hartz jigs, each set being adjusted to treat particles of a certain average size, and the finer material is concentrated on round tables, or buddles, shaking tables, and vanners. The "middlings" from the jigs are usually recrushed or ground and treated again on jigs or on tables. The accompanying concentration scheme (fig. 4) of the Bunker Hill and Sullivan mine will serve to illustrate the general treatment of the ore, although each mill has its own peculiarities of machinery and arrangement designed to meet various local requirements.

As a rule the silver in these ores tends to concentrate in the slimes and at several of the mines fully a third of the value of the total product is said to be saved on the concentrating tables. In the Morning mill, for example, which treats an ore particularly difficult to concentrate successfully, the ordinary coarse concentrates in 1904 carried from 14 to 16 ounces of silver to the ton, while the slimes carried from 18 to 20 ounces.

[a] Since increased to nearly 30,000 horsepower.

The principal lead-silver mills are listed in the following table, which shows also the capacity and motive power of each plant:

*Principal lead-silver mills in the Cœur d'Alene district.*

| Mine. | Approximate capacity in tons per 24 hours. | Power. |
|---|---|---|
| Bunker Hill and Sullivan [a] | 1,000 | Water, with auxiliary electricity from Spokane. |
| Morning | 1,000 | Water, with steam as reserve. |
| Last Chance | 500 | Electricity from Spokane, with auxiliary water. |
| Mammoth | 450 | Water. |
| Standard | 600 | Do. |
| Tiger-Poorman | [b] 700 | Electricity from Spokane, with auxiliary water and steam in reserve. |
| Gold Hunter | 150 | Water. |
| Hecla | 300 | Electricity from Spokane, with auxiliary water. |
| Helena-Frisco | 400 | Not noted; probably water and steam. |
| Hercules [c] | 300 | Probably electricity from Spokane. |

[a] An additional concentrating plant of 1,000 tons capacity has recently been constructed to rework accumulated jig tailings.
[b] This mill in 1904 was running only 12 hours a day and taking about 360 tons of ore.
[c] Erected since district was visited.

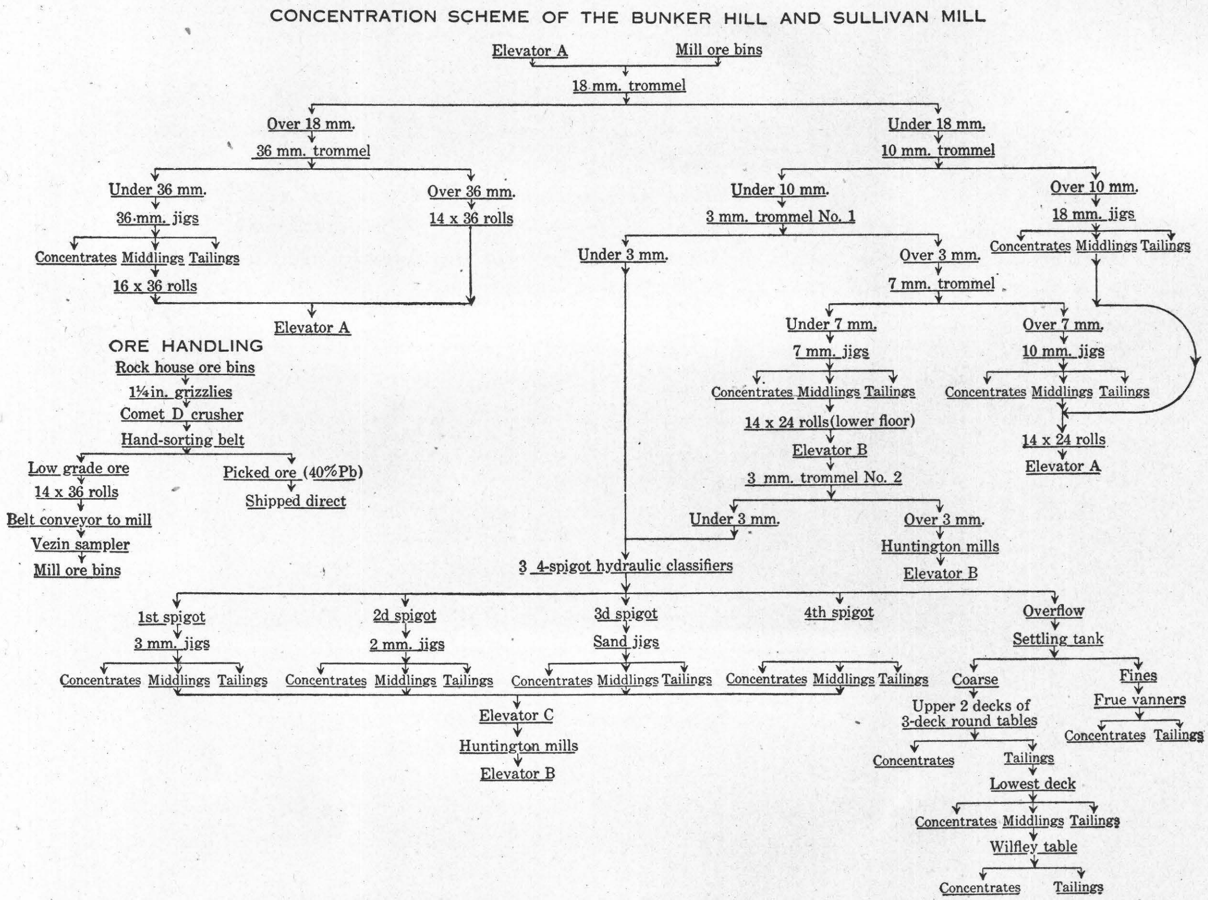



FIG. 4.—Concentration scheme of the Bunker Hill and Sullivan mill.

It will be noticed that local water power plays a very important part in milling operations. Electricity from Spokane, generated by water power also, ranks next, steam being used only as a reserve. The local power is generated almost exclusively by wheels of the Pelton type operated under heads up to 1,500 feet. The largest wheel in the district is the 32-foot Pelton used to drive the compressors of the Morning mine.

Since the district was studied a mill has been built at the Success or Granite mine for concentrating a sphalerite ore. The capacity of the mill is not known. A 200-ton leaching plant for the treatment of copper ore from the Snowstorm mine near Mullan was in process of construction in 1904 and has since been reported in successful operation.

There are a few other lead-silver mills in the district but none of these was in active operation in 1904 and all of them are small or imperfectly equipped. The same may be said of the few gold-milling plants near Murray, all of which were idle in 1904, although the Golden Chest mill was about to resume operations.

# CHAPTER II.—MINERALOGY OF THE ORE DEPOSITS.

## INTRODUCTION.

It is not the purpose of this chapter to describe the occurrence of every mineral that may be known in the Cœur d'Alene district, but only to note those which have some importance or interest in connection with the ore deposits. For descriptions of minerals occurring solely as rock constituents the reader is referred to the preceding account of the general geology by Mr. Calkins.

The arrangement here followed is that adopted by Edward S. Dana in the sixth edition of James D. Dana's System of Mineralogy.

## NATIVE METALS.

*Gold.*—Native gold occurs in quartz veins in the Prichard slate and in placer deposits of local derivation, particularly in that part of the district tributary to the North Fork of the Cœur d'Alene and adjacent to the town of Murray. Some of the quartz formerly mined was very rich and contained coarse free gold. But little of such ore as is worked at the present time, however, contains visible particles of the precious metals.

The principal gangue of the Murray gold veins is quartz, which in the Golden Chest mine contains scattered bunches of scheelite. The sulphides commonly accompanying the gold are auriferous pyrite, chalcopyrite, galena, and sphalerite. Although some galena is found in most of the gold veins, these do not grade into silver-lead deposits. The two types are distinct, gold being practically absent from the deposits worked for lead and silver.

Much coarse gold, in nuggets up to 40 ounces in weight, was obtained from the placers, now nearly exhausted, along Prichard and Beaver creeks. The nuggets as a rule are rough and irregular in shape and usually contain quartz adhering to or embedded in the gold, indicating that they have not traveled far from the veins whence they were derived. The fact that the placer gold contains considerable silver (the nuggets and dust sell for $15 to $18 an ounce) supports this conclusion, as does also the character of much of the gravel in which the gold is found.

Some gold has been obtained also from quartz veins on Elk Creek, near Kellogg, but no work has been done on these deposits for several years. The large, irregular quartz vein of the New Jersey mine, in Gold Run gulch, about 2½ miles east of Kellogg, contains pyrite and tetrahedrite and is said to carry gold enough to make a low-grade ore.

*Silver.*—Native silver in the delicate filiform and mosslike aggregates known as wire silver has been reported from the upper levels of most of the richer lead-silver mines. It was noted at the time of visit in the oxidized ore of the Last Chance mine and particularly in the Hercules mine. It is commonly associated with cerusite and limonite and here and there with minute quantities of malachite or azurite. In the You Like mine (now part of the Morning mine) native silver, cerusite, and plattnerite were associated in the oxidized zone.

## SULPHIDES, SULPHARSENITES, AND SULPHANTIMONITES.

*Stibnite.*—Stibnite, the sulphide of antimony, has been found in this district only in the Gold Hunter mine and in a neighboring prospect, the Enterprise. In the Gold Hunter the stibnite forms small needles or acicular clusters in quartz or, more rarely, in siderite. In some of the quartz the needles project into little vugs. The mineral occurs sporadically in the quartzose parts of the lode, usually near the hanging wall.

It has recently been reported[a] that the Stanley mine, in Gorge Gulch near Burke (see Pl. VIII, p. 86), has been shipping gold and antimony ore to Granite City, Ill. This property was not active in 1904 and it is not known whether the antimony occurs as stibnite or not. The ore is said to assay $25 in gold and 40 per cent of antimony.

*Galena.*—The isometric sulphide of lead is the most important and, with the possible exception of pyrite, the most widely distributed sulphide in the district. It is the essential constituent of the lead-silver ores and is present even in the gold ores of the North Fork.

The mineral occurs massive in this district—very rarely in distinct crystals, and nowhere in such large, well-formed individuals as may be seen in the lead districts of Missouri. The most common form is a rather crumbling granular aggregate, the grains ranging in size from those 4 or 5 millimeters in diameter to those so small that the galena resembles freshly broken steel and is commonly referred to as "steel galena" by the miners. Some of the massive galena of the Hercules mine is unusually coarse for this district, cleavage faces indicating the existence of crystalline individuals up to 2 inches in diameter. The cleavage faces, however, are curved, and the galena in part has an irregular banded structure due to the production of lamellar twinning by pressure. Much of the massive granular galena of the Last Chance mine exhibits a faint banding and rough schistosity which is probably also due to pressure. Mr. Whitman Cross has described a similar structure in galena from the Minnie Moore mine, Bellevue, Idaho.[b] The most characteristic gangue mineral is siderite, but there is usually some quartz present and in a few mines siderite is wholly subordinate. The proportion of galena and gangue varies widely. In some of the lean ores the sulphide is rather sparsely disseminated. In the richer stopes, on the other hand, such as those of the Hercules or of the Wardner mines, it is practicable to sort out a product consisting of lumps of nearly pure galena.

As a rule there is not much sphalerite associated with the galena, the ore of the Granite mine being a notable exception. All of the galena is more or less argentiferous. In some of the mines the fine-grained variety is said to carry more silver than the coarser kinds; but in other mines, such as the Barton, no such relation is recognized. The presence of tetrahedrite with the galena is always a sign of ore rich in silver, but at the time of visit no tetrahedite had been found in the Hercules ore, showing that the presence of the gray copper is not essential to a high tenor in silver.

Among the less common gangue minerals associated with the galena may be mentioned barite, calcite, garnet, and chlorite.

The galena usually oxidizes to cerusite. Pyromorphite occurs in small quantities in some of the oxidized portions of the deposits and plattnerite was found in the upper workings of the Morning (You Like) mine. Anglesite has not been noted in the district.

*Chalcocite.*—Copper glance, cuprous sulphide, has been noted only in the Snowstorm and Park mines, the latter at the time of visit being still in the prospect stage of development. At the Snowstorm it occurs with bornite disseminated through quartzite. At the Park mine, 4 miles south of Mullan, the chalcocite, which has apparently been formed by the action of descending sulphate solutions on pyrite and chalcopyrite, occurs in a vein near the bottom of the zone of oxidation.

*Sphalerite.*—Zinc blende, the sulphide of zinc, is not nearly so common in the Cœur d'Alene district as might be supposed from the abundance of galena. In the concentrates from the Federal Mining and Smelting Company's mines, exclusive of the Morning, the percentage of zinc is usually about 4.5 per cent. In the mines near Wardner sphalerite is never conspicuous and much of the ore is practically free from it. Where visible it has a dark reddish-brown color and forms specks or small irregular bunches in the galena, siderite, and quartz.

In the mines near Mullan zinc blende is more abundant than in the Wardner mines. In the Gold Hunter workings streaks of massive fine-grained sphalerite with pitchy luster and conchoidal fracture are fairly common. The Morning ore, particularly that from the You Like vein, also contains considerable sphalerite in small scattered bunches, in stringers or minutely

[a] Min. and Sci. Press, July 27, 1907, p. 101.

[b] Note on slipping planes and lamellar twinning in galena: Proc. Colorado Sci. Soc., vol. 2, 1887, pp. 171-174.

disseminated among the other minerals. In this mine it is most abundant near the sides of the lode, where the ore grades into country rock.

The mineral is common in the Canyon Creek mines although not generally abundant. Little was seen in the Hercules mine in 1904, but according to Mr. Stanly A. Easton,[a] a small shipment of hand-sorted sphalerite was made in 1905. In the Granite (or Success) mine, on Ninemile Creek, the abundance of sphalerite has led recently to the erection of a concentrating mill for saving the zinc in the ore. The mineral is rather abundant in the Highland Chief and other prospects on Pine Creek.

As a rule, sphalerite is not characteristic of ores rich in lead and silver but rather of the leaner ores, particularly of those accompanied by garnet and other contact-metamorphic minerals. Although some of the mines may yield more sphalerite as they become deeper, there is no present indication that the district will ever produce more than moderate quantities of zinc.

*Covellite.*—In a stope above the first level of the Last Chance mine some rich oxidized ore carrying cerusite and wire silver was seen to be accompanied by streaks of soft, black, sooty material. The deep indigo color of freshly broken lumps and characteristic blowpipe reactions prove that the material is the cupric sulphide, covellite. Most of the lumps inclosed small specks of chalcopyrite, showing that this, perhaps with some tetrahedrite, was the original mineral from which the covellite has been formed in the process of general oxidation.

*Pyrrhotite.*—Magnetic pyrite has not been noted in the mines near Wardner but is fairly abundant in the Canyon Creek and Ninemile Creek mines, although its presence has not been recorded in previous descriptions of the district. It occurs also at the Highland Chief, a prospect near the head of the East Fork of Pine Creek, associated with galena, sphalerite, and a little chalcopyrite.

In the Tiger-Poorman mine a considerable part of the ore on the 1,800-foot level consists of a mixture of massive pyrrhotite, galena, pyrite, sphalerite, and chalcopyrite. Pyrrhotite is fairly abundant also in some of the ore of the 850-foot level of the Standard-Mammoth mine and occurs in the Gem vein of the Helena-Frisco mine and in the Granite and Sixteen-to-One mines.

The concentrates from the Morning mine contain considerable magnetite and it is possible that this mineral is accompanied by a little pyrrhotite. The presence of the latter, however, could not be definitely established.

*Bornite.*—The isometric sulphide of copper and iron—peacock ore, as it is sometimes called—occurs with chalcocite in the Snowstorm mine and in several prospects north and east of Mullan. Among these may be mentioned the Copper King in Sonora Gulch and the Silver Cliff near Lookout station, on the Northern Pacific Railway. The mineral is not known in the lead-silver deposits, although it is associated with small quantities of galena at the Silver Cliff.

*Chalcopyrite.*—Copper pyrite, though not abundant in the district, is distributed sparingly through most of the ore bodies. According to Mr. Stanly A. Easton, it has been observed in the Bunker Hill and Sullivan mine but is decidedly rare. None was seen in this mine at the time of visit although it was noted at a few places in the adjoining Last Chance mine. Chalcopyrite is fully as rare in the mines near Mullan as in those near Wardner. A few small specks were seen in the Gold Hunter mine and the mineral is probably not entirely absent from the ore of the Morning mine. In some of the Canyon Creek mines it is a little more abundant, being in most places accompanied by pyrrhotite. It was noted particularly in a stope above the 450-foot level of the Standard-Mammoth mine and is present with pyrrhotite in small quantities in the Helena-Frisco mine. It is found occasionally in the Tiger-Poorman and Hercules mines but is rare or absent in the Hecla mine. A little of the mineral occurs in the Granite and Sixteen-to-One ores, as well as in the Bear Top ore and in many of the gold veins near Murray.

While chalcopyrite is a very unimportant constituent of the ores of the large lead-silver mines, it is distributed rather widely over the district and is moderately abundant in several prospects, among which may be mentioned one on the north bank of the river about a mile east

[a] Eng. and Min. Jour., vol. 81, 1906, p. 11.

of Kellogg, one on Placer Creek about 2 miles south of Wallace, and the Park mine, about 4 miles south of Mullan. A little chalcopyrite occurs also in the copper ore of the Snowstorm mine and in the Silver Cliff, Copper King, and other prospects in the so-called copper belt of Mullan.

*Pyrite.*—The common disulphide of iron is here, as in most districts, a very abundant and widely distributed mineral. It occurs in all the lead-silver deposits, particularly in the leaner parts of the lodes, where it is practically a valueless gangue, as it does not contain appreciable quantities of the precious metals. In the richer mines pyrite may be very inconspicuous or even rare in those parts of the ore body where galena is most abundant, in which case there is usually a gradation outward from a central mass of good ore through leaner and more pyritic varieties into country rock. Although no hard and fast rule of association can be laid down, it is noticeable that quartz and pyrite exhibit a tendency to occur together and that galena and siderite have a similar affinity.

Pyrite, probably most of it auriferous, occurs in all the gold-quartz veins near Murray and in other parts of the district. In the Golden Chest mine it is intimately associated with scheelite, and is known to be auriferous.

It is also present in disseminated crystals, many of them microscopic, in the country rock near both the lead-silver and gold deposits. No large bodies of the mineral are known in the district, although it is possible that some may appear at depths greater than those now attained.

*Proustite.*—Ruby silver, or proustite, occurs in small distorted crystals in the Yankee Boy mine on Big Creek, occupying minute fissures in the green slate of the Wallace formation. The mineral possibly occurs also in some of the other silver mines of the so-called dry belt, between Wallace and Wardner, but none was seen in 1904.

*Tetrahedrite.*—Tetrahedrite, or gray copper ore, essentially a sulphantimonite of copper in which part of the copper may be replaced by silver or other metals and part of the antimony by arsenic, is not abundant in the Cœur d'Alene district. It occurs in small quantities, however, in the ores of several of the lead-silver mines and is generally a sign of ore rich in silver. No tetrahedrite was seen in the Bunker Hill and Sullivan mine at the time of visit, but it is said to have been found in the Sullivan and Tyler workings of this property. It occurs rather sparingly with rich ore in the Last Chance and Sierra Nevada mines. In the Gold Hunter mine, near Mullan, tetrahedrite is fairly abundant in the old upper tunnels but is not known in the levels now worked by the company. It occurs in small quantity in the You Like vein of the Morning mine, in the Alice, a prospect in Ruddy Gulch about 2 miles west of Mullan, in the Standard-Mammoth mine, in the Yankee Boy mine on Big Creek, in the Polaris mine in Polaris Gulch, and in the Copper King, a prospect near the head of Sonora Gulch.

The tetrahedrite of the Cœur d'Alene district, as tested by Dr. W. F. Hillebrand, appears to be nearly all of the antimonial variety, containing little or no arsenic. Analyses of ores made at the sampling works of the Federal Mining and Smelting Company show occasionally a fraction of 1 per cent of antimony but no arsenic. An arsenical and mercurial variety, however, occurs at the Polaris mine.

A chemical test by Dr. W. T. Schaller of tetrahedrite from the Gold Hunter mine showed the presence of considerable silver and the frequent association of this mineral with rich ore leaves little doubt of its prevailingly argentiferous character.

As a rule the mineral occurs in small quantity and so mixed with galena and other sulphides as to render it difficult to procure satisfactory material for chemical analysis. It is possible that other sulphantimonites than tetrahedrite may also be present in some of the ores of the district. A gray mineral from the Standard-Mammoth mine, supposed when collected to be tetrahedrite, was determined by Doctor Schaller to consist of copper, sulphur, and antimony, but from its reaction when heated in a closed tube he concluded that it is probably not tetrahedrite but the rarer copper sulphantimonite chalcostibite, which has the formula $Cu_8Sb_2S_7$. The material, however, is not sufficiently pure for complete chemical analysis and the results obtained scarcely warrant more than a suggestion that some of the "gray copper" of the ores may in future turn out to be chalcostibite.

## OXIDES.

*Quartz.*—Quartz is present in all the ore deposits in the Cœur d'Alene district, but varies greatly in abundance. In most of the large lead-silver mines it is subordinate as a gangue mineral to siderite, and in some, like the Bunker Hill and Sullivan, quartz is almost absent from the best ore. In the gold veins near Murray, however, quartz is the principal gangue mineral and even in some of the lead-silver mines—for example, the Hecla, at Burke—it is more abundant than siderite.

The quartz of the lead-silver deposits is generally milk-white and massive, most of it being irregularly intergrown with siderite and ore minerals. In some places quartz and siderite are contemporaneous, both having replaced the quartzite at practically the same time. In others the quartz forms sharply defined veinlets which in the Bunker Hill and Sullivan and Standard-Mammoth mines cut ore consisting in part of an earlier generation of the same mineral. In the Hecla mine, on the other hand, quartz stringers were observed which appeared to be older than the ore. In the Last Chance and Bunker Hill and Sullivan mines, some of the best ore in the Jersey or Skookum fissure zone consists of massive galena with a small quantity of quartz gangue and no siderite. Part of the quartz occurs as isolated crystals in the galena, some of these crystals being several inches in length and most of them having rough, rounded, and distorted forms. This particular ore shows less evidence of replacement than the ore with sideritic gangue and has, in part at least, crystallized in open fissures. Comb structure, vugs, well-bounded quartz crystals, and other features associated with filled fissures are, however, wholly exceptional in the lead-silver deposits.

In most of the gold deposits, on the other hand, the quartz has the character usually associated with fissure veins, replacement being here wholly subordinate to the filling of open spaces. A banded structure (Pl. XVI, p. 142) is very prevalent in the gold veins near Murray and, as shown on page 142, has probably resulted from repeated openings and fillings along the veins.

*Cuprite.*—The red oxide of copper occurs in the Cœur d'Alene district, so far as known, only in the Snowstorm mine, where it has formed by the oxidation of cupriferous sulphides disseminated through quartzite.

*Massicot.*—Lead monoxide, or natural litharge, occurs as a more or less impure yellow powder in some of the oxidized ores, usually associated with cerusite. The mineral was noted particularly in the Hercules, California, and Standard-Mammoth mines, but is probably present also in others. When mixed with limonite, the massicot is easily overlooked owing to its yellow color and earthy character.

*Magnetite.*—Magnetite occurs in some of the ore of the Granite mine, intergrown with sphalerite and associated with galena, quartz, garnet, pyroxene, and a green mica probably related to biotite. It may be present also in the Gem vein of the Helena-Frisco mine and in the Sixteen-to-One mine, as these deposits resemble mineralogically that of the Granite mine.

Although neither magnetite nor pyrrhotite was noted in the ore of the Morning mine, it is possible with a weak magnet to extract magnetic particles from the mill concentrates. These fragments, some of which are as large as a pea, when examined with a lens show galena, sphalerite, pyrite, and a little quartz or siderite. Even with the knowledge of the magnetic property, it is difficult to detect the presence of any other constituent, although there is a suggestion of some darker mineral, presumably magnetite, intergrown with the galena. By pulverizing one of the magnetic fragments it is possible to separate the highly magnetic particles from the other minerals and to examine them under the microscope. Here they show the characteristic color of magnetite and an occasional suggestion of an octahedral face. Most of the grains, however, are ragged and the mineral probably occurs irregularly intergrown with the sulphides and not as idiomorphic crystals.

It is not known in what part of the ore bodies the magnetite occurs, as it has been found only in the concentrates. A careful inspection of all the ore specimens collected from various parts of the mine has failed to reveal its presence.

The presence of magnetite as a vein mineral associated with sulphides is of considerable interest. Lindgren[a] has recorded its occurrence as a product of rock alteration in the Melones mine on Carson Hill, California.

Outside of the Morning mine and contact zones of the syenite, magnetite has not been recognized as a constituent of the ores, although it is widely distributed as a primary mineral in all the eruptive rocks of the region and is probably disseminated sparingly through some of the sediments.

Minute black octahedrons, which when crushed give the characteristic streak of hematite, were noted by Mr. Zalinski incrusting loose fragments from the Prichard formation on the trail below the Bear Top mine, 5 miles east of Murray. These consist of the isometric form of ferric oxide known as martite and believed by most mineralogists to be a pseudomorph of hematite after magnetite or possibly in some cases after pyrite. The mineral or pseudomorph is of no economic importance and is mentioned merely to record its presence in the district.

*Limonite.*—The hydrous oxide of iron is present in all of the oxidized ore as an alteration product of pyrite and siderite. It has the usual spongy or powdery form of the mineral and calls for no special description.

*Plattnerite.*—The rare mineral plattnerite, the tetragonal form of the dioxide of lead, occurred in the upper tunnel of the You Like mine, now part of the Morning group, near Mullan, in nodules associated with pyromorphite and limonite. Prior to its discovery at this locality the mineral had been found only in Scotland and the validity of the species had been questioned by Dana and others. Crystals from the You Like mine were studied by Yeates and Ayres[b] and their work established plattnerite as a mineral species crystallizing in the tetragonal system.

Although at the time of visit a few specimens of massive plattnerite could be seen in the town of Mullan, the stopes whence the material came have long been worked out and abandoned.

## CARBONATES.

*Calcite.*—Calcite is not common in the Cœur d'Alene ore bodies. A few rhombohedral crystals occur in vugs in galena in the Hecla mine and the mineral makes up a minor part of the gangue here and there in the Morning mine. In massive form, with quartz, it is rather abundant in the ore body of the Bear Top mine, 5 miles east of Murray.

*Dolomite.*—The carbonate of calcium and magnesium is not a common gangue in the Cœur d'Alene ores, but was noted in the Silver Cliff, a copper prospect east of Mullan.

*Siderite.*—The carbonate of iron, often known as spathic iron, is the most abundant and characteristic gangue mineral of the Cœur d'Alene lead-silver deposits and its presence as a replacement of quartzite constitutes a striking mineralogical feature of the ores. In fact the deposits in this respect are unique among the known ore bodies of the world. According to Lindgren,[c] siderite occurs as a gangue in the lead-silver veins of the Wood River district, Idaho, where it replaces calcareous shales. It is known also as a gangue mineral in the lead ores of the Iglesias district in Sardinia and sparingly in the lead deposits of Linares, Spain. In none of these places, however, does the mineral replace quartzite, nor does it constitute so large a proportion of the gangue as in the Cœur d'Alene district.

In the typical Cœur d'Alene deposits the siderite is massive, the ordinary gangue of the Bunker Hill and Sullivan mine, for example, being a pale-brown, fine-grained aggregate of siderite not always distinguishable at a casual glance from the quartzite which it has in part replaced. In the vicinity of the ore bodies all gradations can be observed between nearly pure massive siderite and a usually somewhat sericitic quartzite. Coarsely crystalline varieties are comparatively rare and are confined to those veins or parts of ore bodies in which the ore has

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[a] Metasomatic processes in the gold deposits of Western Australia: Economic Geology, vol. 1, 1906, p. 544.

[b] Yeates, William S., Plattnerite, and its occurrence near Mullan, Idaho; with crystallographic notes by Edward F. Ayres: Am. Jour. Sci., 3d ser., vol. 43, 1892, pp. 407-412.

[c] The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 213.

# PLATE IX.

## Photomicrographs Illustrating Replacement of Quartzite by Siderite.

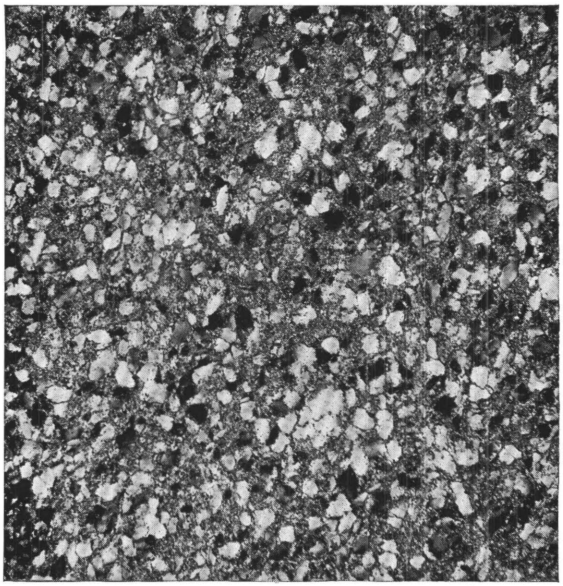
*A*. Revett quartzite (I 98) from Morning road, one-half mile northwest of Mullan. Shows grains of quartz in an abundant matrix consisting of sericite and finely crystalline quartz. This rock contains a little pyrite, zircon, and tourmaline, but no siderite. Magnified 30 diameters. Nicols crossed.

*B* Revett quartzite partly replaced by siderite (I 43), from Bunker Hill and Sullivan mine, third level. The darker part of the field, in the upper left-hand quadrant, is chiefly siderite which has replaced a sericitic matrix similar to that shown in *A*. A nest of secondary quartz (*q*) has also formed near the siderite, in the upper right-hand quadrant of the field. Magnified 30 diameters. Nicols crossed.

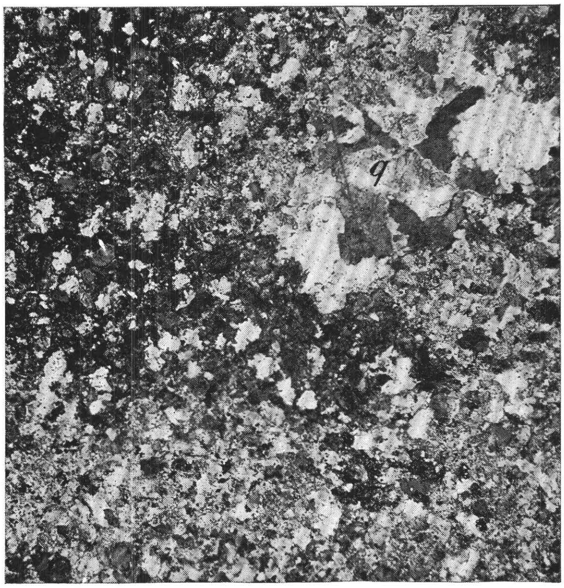
*C* Revett quartzite (I 88) from Morning mine, showing development of siderite (*s*) throughout the rock, particularly as a replacement of the original sericitic matrix. The siderite is distinguishable from the quartz by its darker tint and apparently rougher surface. Magnified 30 diameters. Ordinary light.

*D*. Same as *C*. Nicols crossed. The siderite (*s*) here has a fine-speckled appearance while the quartz grains (*q*) are uniform in tint.

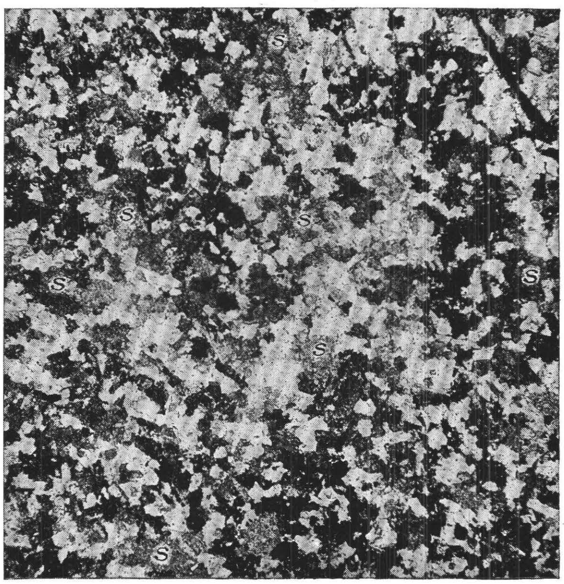
*E*. Veinlet of siderite (*s*) in quartzite (*q*) (I 28) from the Bunker Hill and Sullivan mine. Illustrates tendency to develop along cracks and to extend outward by irregular replacement. The veinlet is faulted by a cross fracture along which a little pyrite has developed. Magnified 30 diameters. Ordinary light.



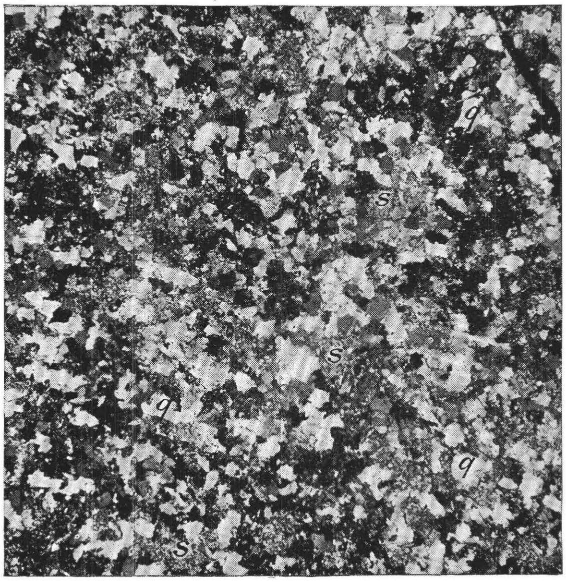
*A*



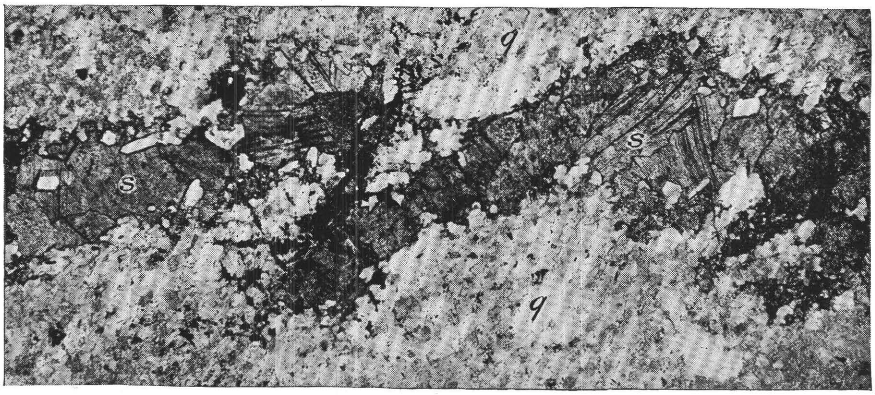

*B*




*C*




*D*




*E*

PHOTOMICROGRAPHS ILLUSTRATING REPLACEMENT OF QUARTZITE BY SIDERITE.

filled open spaces or diaclases. The mineral is in such cases usually associated with ordinary vein quartz, as in the Union and Argentine mines.

Siderite is by no means equally abundant in all the mines. It is a particularly prominent constituent in the ores of the Wardner and Mullan groups. In the Canyon Creek group the mineral is fairly abundant in the Tiger-Poorman and Standard-Mammoth lodes, but in the Helena-Frisco and Hercules it is rather inconspicuous and in the Hecla mine occurs sparingly as a microscopic constituent. So far as could be seen in 1904, the ores of the Ninemile Creek group of mines contain no siderite, and it appears to be entirely absent from the gold-quartz veins in the vicinity of Murray.

The mineral, though especially abundant near certain areas of intense mineralization, is by no means confined to the ore bodies or to their immediate vicinity but is widely distributed through the quartzitic rocks of the district. Mr. Calkins finds, however, that although siderite has a much wider distribution than the ores, yet it is most abundant where the rocks have been most folded and fissured. It apparently forms more readily in some rocks than in others, being abundant in the Burke and in parts of the Prichard formation but rare in the calcareous rocks of the Wallace.

The siderite is visible in few weathered exposures owing to its ready decomposition to limonite in accordance with the general reaction—

$$4FeCO_3 + 3H_2O + O_2 = Fe_2(OH)_6.Fe_2O_3 + 4CO_2.$$

Consequently its presence in such rocks is usually indicated by rusty streaks or specks. The above-stated reaction takes place in the oxidation of ores with siderite gangue and accounts for the abundant production of limonite and cerusite.

The following note on the microscopic characteristics of siderite as it appears in specimens of country rock has been supplied by Mr. Calkins:

> Siderite occurs in individuals of varying size; but probably the majority of them are larger than the clastic grains of the rock, the mineral being in places crystallographically continuous for a diameter of several millimeters. The form of the individuals varies much in regularity. The outlines of many of them, especially of the larger grains, appear ragged, but in such cases the boundaries are seen on close examination to be determined in large part by rhombohedral planes. In other individuals the rhombohedral form of the crystal is more marked, in some being perfect. It is an important fact that in any specimen the crystallographic boundaries can be seen cutting sharply across quartz grains, which proves that the siderite has been developed by molecular replacement of the quartz and not by filling in of cavities. The larger grains in the sandstones and quartzites frequently inclose grains of quartz and, much less commonly, scales of sericite. It is thus evident that the siderite replaces the sericitic fine-grained cementing material more readily than the larger grains of quartz.

In the vicinity of the large ore bodies near Wardner or in the Morning mine near Mullan, all the intermediate steps can be studied from sericitic quartzite on the one hand to massive siderite on the other. These are partly illustrated in Pl. IX, Pl. XII, *C* and *D* (p. 102), and Pl. XIII (p. 110). The process of replacement has gone on most rapidly and thoroughly where the quartzite has been fissured, for such fissuring not only gives the metamorphosing solutions free access to the rock but provides open spaces where the iron carbonate can deposit without removal of other materials. But the process is not closely dependent on fissuring. Much of the quartzite contains siderite disseminated through its mass, even where no microscopic cracks are visible. In such rock the siderite replaces first the fine sericitic matrix between the quartz grains or aggregates of the carbonate form about scattered centers of crystallization. In those specimens where the siderite has filled cracks in the quartzite the resulting veinlets never show clean-cut walls but the carbonate has replaced the quartzite to varying distances from the original crack, as illustrated in Pl. IX, *E*.

*Cerusite.*—Cerusite, the carbonate of lead, is the most characteristic mineral of the oxidized ores and still supplies a considerable part of the lead produced from the Hercules and Last Chance mines. In most of the large mines, however, the carbonate ore has long since been exhausted. In the typical oxidized ore the cerusite occurs in lustrous white or transparent orthorhombic crystals, many of them strongly striated, associated with limonite and locally with wire silver and massicot, or natural litharge. The mineral, however, is not restricted to

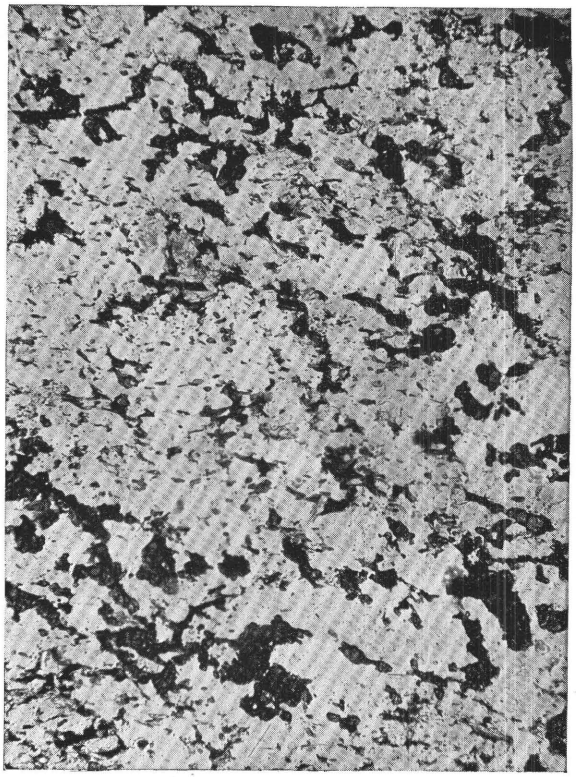
# PLATE X.

## PHOTOMICROGRAPHS SHOWING RELATION OF ORES TO CONTACT METAMORPHISM.

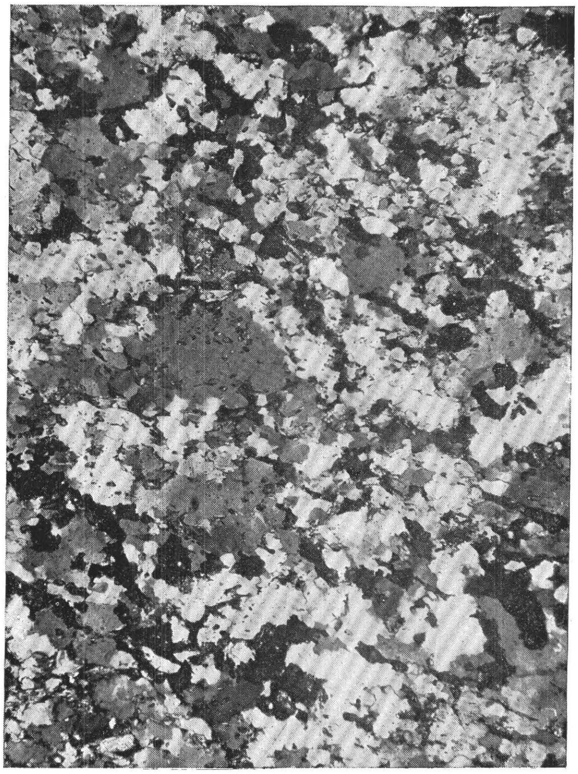
*A*. Altered Burke quartzite (I 203) from Gem workings in Helena-Frisco mine. The dark, irregular areas are garnet; the lighter, shredlike particles are green biotite; the colorless matrix is quartz. There are also a few small crystals of pyrite, not distinguishable in the photograph from the garnet. Magnified 40 diameters. Ordinary light.

*B*. Same as *A*. Nicols crossed, showing granular texture of the quartz.

*C*. Ore (I 207) from Granite mine, showing association of sulphides with contact-metamorphic silicates. On left side of the field is clear quartz (*q*) in large interlocking grains containing crystals of biotite, sphalerite, pyrite, and galena. The dark middle band consists of the same sulphides embedded in garnet with a little quartz. This band is fringed with garnet (*g*) on the right. The light band in the right of the field is quartzite crowded with garnet, biotite, and small crystals of pyrite. Magnified 40 diameters. Ordinary light.



*A*



*B*


*C*

PHOTOMICROGRAPHS SHOWING RELATION OF ORES TO CONTACT METAMORPHISM.

the zone of conspicuous oxidation but is common in little crevices or vugs in the sulphides, crystals of cerusite being in many places implanted on unaltered galena by solutions that have percolated down from the zone of general oxidation.

The only mine in which large crystalline masses of cerusite could be seen at the time of visit was the Hercules, which, being the youngest mine in the district, had not yet exhausted its oxidized ore. Here occur large masses of carbonate ore with numerous vugs lined with brilliant but exceedingly fragile crystals of cerusite associated with wire silver and massicot.

The Bunker Hill and Sullivan, Last Chance, Morning (You Like claim), and Standard-Mammoth mines all had rich bodies of cerusite ore in their upper levels and none of the lead-silver mines is without some of this mineral.

At the California mine some of the crystals are smoky gray to nearly black.

*Malachite.*—The green hydrous carbonate of copper is of economic importance only at the Snowstorm mine, where it is disseminated through quartzite and is one of the constituents of the siliceous copper ore there mined. In the lead-silver mines malachite results from the oxidation of chalcopyrite of tetrahedrite and is nowhere abundant. It is present also in many prospects where inconsiderable quantities of copper sulphides have undergone oxidation.

*Azurite.*—The blue hydrous carbonate of copper is known in the Cœur d'Alene district only as specks or films accompanying malachite.

## SILICATES.

*Pyroxene.*—No pyroxene has been noted in the ores, but a pale-green or colorless monoclinic species, probably diopside, is abundant in some of the contact-metamorphosed sediments near the monzonitic intrusions. It was noted particularly in the Alameda tunnel, near the Granite mine, where some originally calcareous band in the sediments has been changed to a dense aggregate of diopside, quartz, and green hornblende.

*Amphibole.*—Common green hornblende occurs, usually with diopside and biotite, in some of the contact-metamorphosed sediments, but not, so far as known, as an ore constituent.

*Anthophyllite.*—At one place in the Hercules mine a small quantity of a light-gray, silky asbestiform mineral was found crystallized with galena. Under the microscope the exceedingly fine fibers show rather low double refraction and parallel extinction. The mineral, as tested by Dr. W. T. Schaller, is not attacked by acids and fuses with difficulty. It is probably anthophyllite, a comparatively rare mineral, occurring in crystalline schists. Its presence in an ore deposit, intergrown with galena, is decidedly unusual.

*Garnet.*—Small crystals of reddish garnet are fairly abundant in the contact metamorphic zones that surround the intrusive masses of monzonite north of Canyon Creek. The mineral occurs also as a gangue constituent, intergrown with metallic sulphides and magnetite, in ore deposits situated within the metamorphic zones, particularly in the Helena-Frisco, Custer, Granite, and Sixteen-to-One mines. (See Pls. X, XI, and XII.) In the last two properties some of the crystals are large enough to be recognized by the naked eye, but for the most part the mineral is microscopic. In the Granite mine, for example, a pink tint which is characteristic of the quartzite close to an ore body is seen in thin section to be due to the presence of numerous microscopic garnets.

In the course of the present investigation no garnet has been found in ore bodies lying outside of the recognizable range of contact metamorphism due to the monzonitic intrusions. The ore bodies near the syenite, moreover, differ in other mineralogical features, as is shown on page 136, from those near Wardner, Burke, and Mullan. According to Lindgren,[a] however, garnet was found in some specimens collected by him in the Bunker Hill and Sullivan mine. None of the many specimens collected from this and other mines near Wardner in the course of the present investigation shows any garnet nor are the ores of a mineralogical character suggestive of the presence of this mineral. Lindgren himself remarks, "I have mentioned these peculiar products of replacement because they differ so completely from the deposits as described above. Their formation must be sought in some local cause, involving a change in the mineral-bearing solutions; or in the conditions of the deposition."[b]

[a] Metasomatic processes in fissure veins: Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 682.

[b] Op. cit., p. 682.

# PLATE XI.

## Photomicrographs of Ores and Rocks.

*A*. Metamorphosed quartzite (I 263) from Granite mine, showing development of garnet (*g*) as irregular aggregates in the clear quartz matrix (*q*). Magnified 40 diameters. Ordinary light.

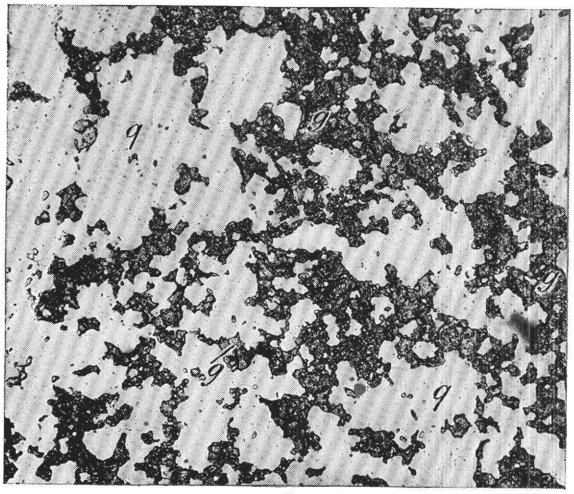
*B*. Same as *A*. Nicols crossed.

*C*. Metamorphosed Prichard country rock (I 260) from the Sixteen-to-One mine, showing development of garnet. The dark circular area, about three-fourths of an inch in diameter, is garnet with included quartz grains. Magnified 30 diameters. Nicols crossed.

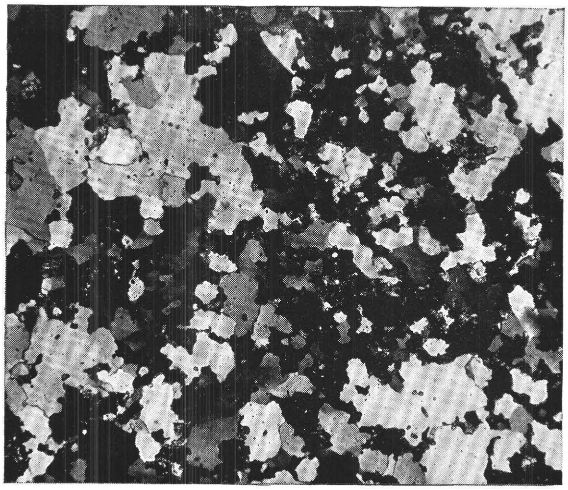
*D*. Scheelite (I 234) from the Golden Chest mine, showing relation to quartz (*q*) and pyrite (black). Magnified 30 diameters. Ordinary light.

*E*. Ore (I 117) from the Snowstorm mine, showing the occurrence of chalcocite (black) in microscopic fractures in Revett quartzite. Magnified 30 diameters. Ordinary light.

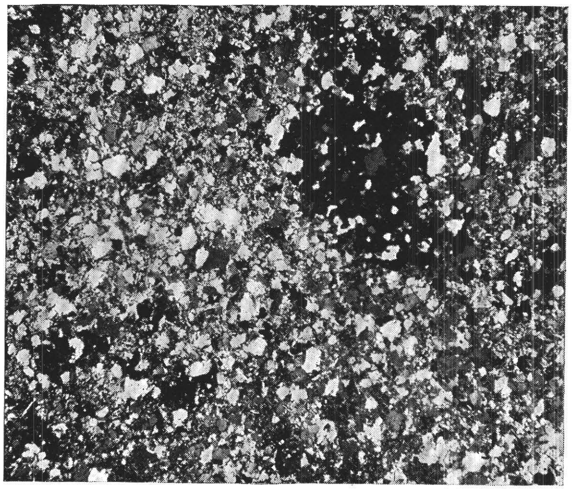
*F*. Same as *E*. Nicols crossed.



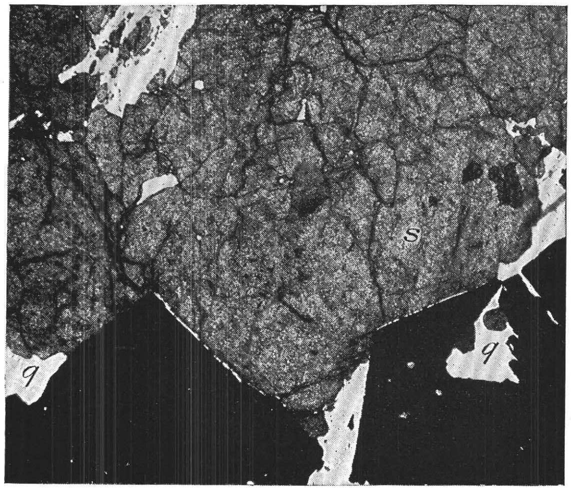
*A*



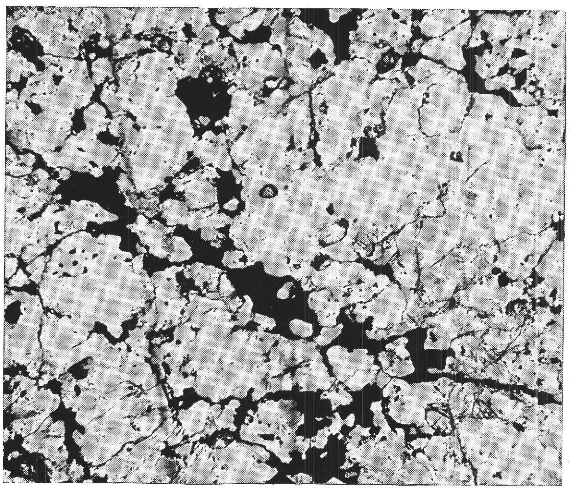
*B*



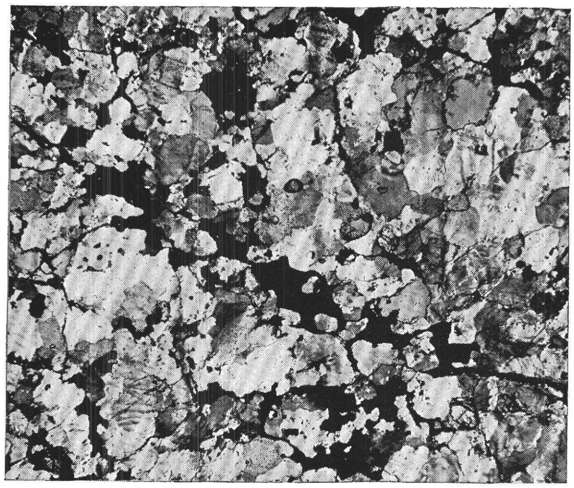
*C*



*D*



*E*



*F*

PHOTOMICROGRAPHS OF ORES AND ROCKS.

On the other hand, in the Helena-Frisco mine, also visited by Lindgren, garnet does occur, although he does not mention it, and thin sections made from specimens collected in this mine resemble very closely the section studied by Mr. Lindgren, which he kindly placed at my disposal for comparison.

It is difficult to reconcile the reported occurrence of garnet at the Bunker Hill and Sullivan mine with the great distance of the mine from the contact zones to which the mineral is apparently confined and with the absence from the Wardner deposits of the other minerals characteristic of the ores near the syenite. Such an exceptional occurrence would introduce so disturbing a factor into a body of facts otherwise consistent and explainable that it seems reasonable to suggest that in some manner the specimens or thin sections studied by Mr. Lindgren had been confused and that the specimen thought to come from the Bunker Hill and Sullivan mine really came from the Helena-Frisco mine.

The garnet crystals of the Sixteen-to-One mine are pale red or pink, and in thin section all of the mineral seen in the district is faintly rose tinted or colorless. It occurs usually in irregular microscopic grains intergrown with quartz, a green mica, here and there tourmaline, magnetite, pyrrhotite, pyrite, sphalerite, galena, and chalcopyrite. Sharply bounded crystals are rare.

*Tourmaline.*—As a microscopic constituent tourmaline is widely disseminated throughout the sedimentary rocks of the Cœur d'Alene district in the form of irregular grains and imperfectly terminated prisms.

Mr. Calkins, who has studied the occurrence of the tourmaline in the area at large, regards it as a secondary constituent and not, like zircon, a mechanical inclusion in the sediments. It is never found in waterworn grains. He finds that, like siderite, tourmaline is most abundant where the rocks have been most disturbed. It does not, however, exhibit any such close relation to the monzonitic intrusion as to lead to its classification as an ordinary contact-metamorphic mineral. As a rule tourmaline crystals are most numerous and best developed in the finer-grained sediments, particularly those having an abundant sericitic matrix. The coarse, highly siliceous quartzites and the calcareous rocks of the Wallace formation are apparently the least favorable to the development of the mineral.

In close association with ore minerals and clearly of secondary origin, tourmaline occurs in the little veinlet in the interesting specimen collected by Mr. Lindgren and referred to on page 99.

*Biotite.*—A black biotite, apparently of the ordinary variety with characteristic yellow-brown pleochroism and strong absorption, is a common microscopic constituent in the contact-metamorphic zones around the syenitic intrusions north of Canyon Creek. Within these zones, however, the ores generally contain a little mica which, while resembling ordinary biotite in habit, mean refractive index, and birefringence, is green in transmitted light. The pleochroism is strong, ranging from deep grass-green to faint yellow, and the absorption scheme is the same as in ordinary biotite. There is apparently no very sharp distinction possible between this green mica and the black or brown biotite, both being in many places closely associated. Furthermore, some thin sections show an apparent gradation from the brightly polarizing green mica to chlorite. A similar green biotite has been noted at Cripple Creek.[a]

It is well known that the early stages of the hydrometamorphism or hydrothermal metamorphism of biotite are characterized by the exchange of brown for green tints in transmitted light. It is possible that the green mica in the Cœur d'Alene deposits is a biotite that has thus undergone incipient alteration, although there is no evidence that the change is due to any of the processes embraced within the term weathering. It seems rather to be a deep-seated alteration or variation connected with ore deposition.

*Chlorite.*—This mineral, which is not always readily distinguishable from the green biotite just described, is not abundant in the Cœur d'Alene ores. It occurs in a few places, for example, near the Bitter Root prospect, south of Mullan, as an interstitial material in the quartzites,

[a] Lindgren, W., and Ransome, F. L., Geology and gold deposits of the Cripple Creek district: Prof. Paper U. S. Geol. Survey No. 54, 1906, p. 128.

## PLATE XII.

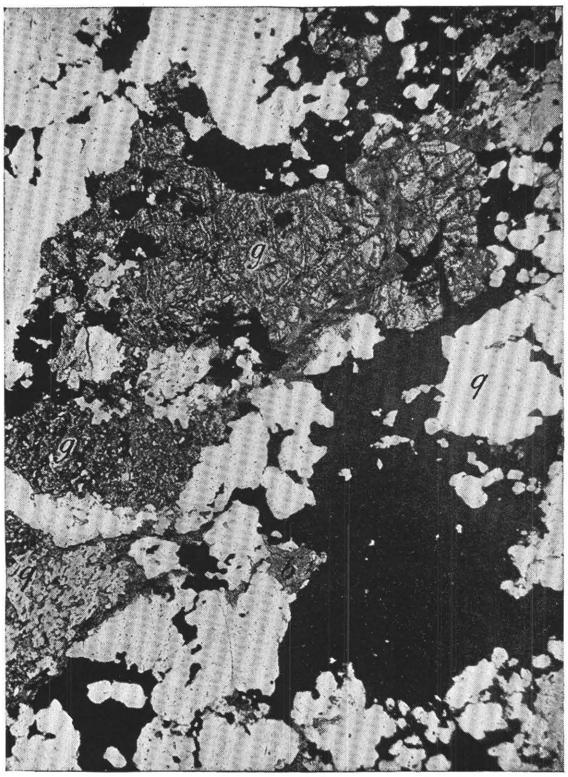
### Photomicrographs of Ores.

*A*. Ore (I 261) from the Sixteen-to-One mine, showing recrystallization of garnet (*g*), quartz (*q*), biotite (*b*), and sulphides (black). The sulphides consist chiefly of pyrrhotite with subordinate galena. Magnified 30 diameters. Ordinary light.

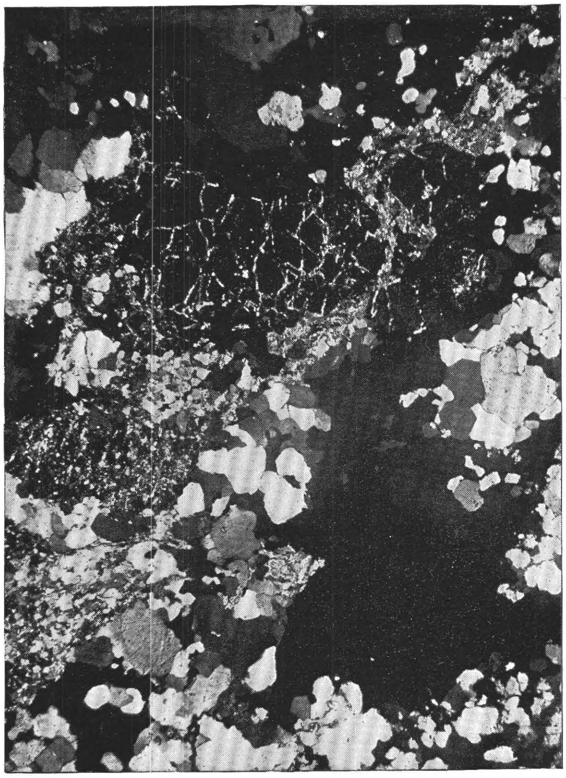
*B*. Same as *A*. Nicols crossed, showing granular texture of quartz.

*C*. Ore (I 191) from the Hecla mine, showing replacement of quartzite (*q*) by siderite (*s*) and galena (black).

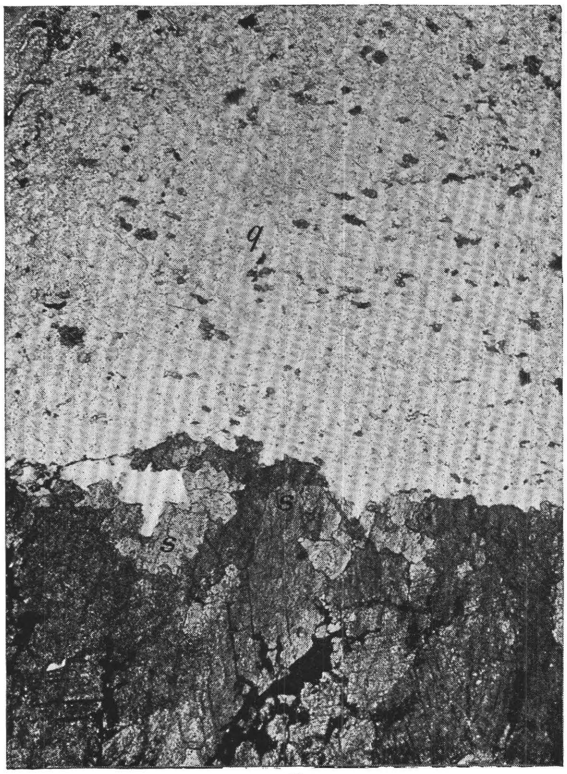
*D*. Ore (I 146) from the Standard-Mammoth mine, showing relation of galena (black) to siderite (*s*) and quartz (*q*). Magnified 30 diameters. Ordinary light.



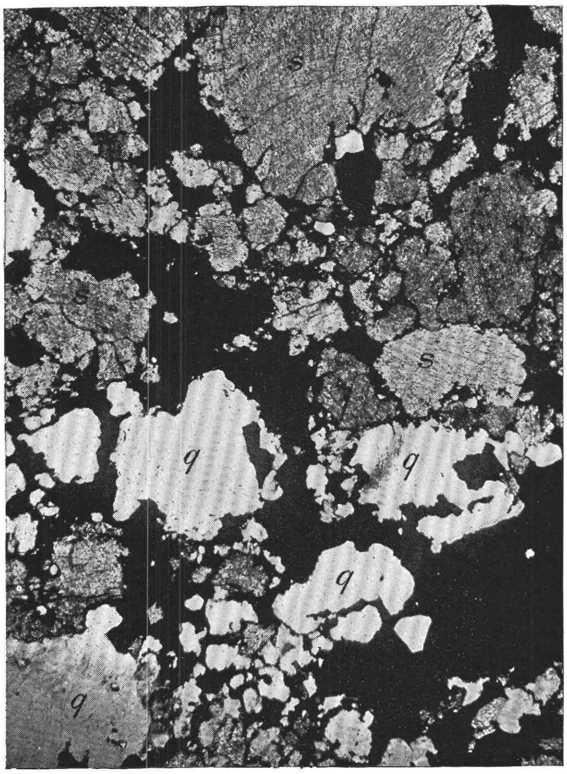

*A*



*B*




*C*




*D*

PHOTOMICROGRAPHS OF ORES.

taking the part usually played by sericite. It is sparingly present, associated with green biotite, in the Hercules ore and probably also in some of the ores of the Ninemile Creek group of mines.

## PHOSPHATES.

*Pyromorphite.*—The chlor-phosphate of lead, in characteristic small yellowish-green hexagonal prisms squarely truncated by the basal pinacoid, is abundant in the Little Giant prospect in Silver Gulch, southeast of Mullan. The crystals form sparkling druses in limonite derived from the oxidation of siderite. Pyromorphite occurs also in the Bitter Root, a prospect in Boulder Gulch, south of Mullan; in the upper tunnel of the Hercules mine; in the Senator Stewart mine, near Wardner; and probably elsewhere in the oxidized portions of the lead-silver deposits. It was associated with plattnerite in the now abandoned upper tunnel of the You Like mine.

This mineral is apparently one of the latest to form and is characteristic of the upper parts of the zone of oxidation. It occurs in crusts or druses on limonite and cerusite and in cracks in the decomposed country rock near the oxidized ore.

## SULPHATES.

*Barite.*—The sulphate of barium is not widely distributed as a gangue mineral but occurs in great abundance in certain parts of the Gold Hunter mine. Here it forms a compact white gangue carrying thin sheets of galena, sphalerite, and tetrahedrite, which give the ore a striking banded appearance. It occurs also as stringers in the country rock. The only other occurrence of barite known in the district is at the Little Giant prospect, about 2 miles southeast of Mullan, where it is associated with galena in a vein. Analyses of ore made at the sampling works near Wallace show that there is considerable barite in the Standard-Mammoth mine, although the mineral is not noticeable in the specimens collected.

## TUNGSTATES.

*Scheelite.*—The interesting mineral scheelite, the tungstate of calcium, occurs massive in irregular bunches in the Golden Chest mine near Murray intergrown with the quartz, pyrite, sphalerite, and galena of the vein, as shown in Pl. XI, *D* (p. 100). The mineral is readily recognized by its high specific gravity (5.9–6.1), which is much greater than that of barite. Some tons of this material, much of it in large, nearly pure lumps, has been thrown aside on the dump of the mine. As scheelite contains about 80 per cent of tungsten trioxide it has value as a source of tungstic acid. None of the mineral from the Golden Chest mine has been marketed so far as known.

# CHAPTER III.—DESCRIPTION OF THE LEAD-SILVER DEPOSITS.

## GEOGRAPHICAL AND GEOLOGICAL DISTRIBUTION.

The general distribution of the lead-silver ores was briefly indicated in the introductory chapter (pp. 84–85). It is proposed in the following pages to supplement that outline by additional details and to describe particularly the relations of the deposits to the various geological formations into which the sedimentary rocks of the district have been divided.

The question whether the distribution of the ore bodies has any genetic connection with the distribution of particular kinds of rock is scientifically and practically very important. Unfortunately, the thick series of Algonkian sediments is not divisible into formations that are lithologically distinct and homogeneous. Sands and silts accumulated on the subsiding bottom of the shallow pre-Cambrian sea to a thickness of more than 15,000 feet. So shallow was this sea that most of the sediments retain the marks of ripples and were occasionally laid bare and cracked by the sun. Throughout the entire period of deposition there was no abrupt change in the general character of the sediments. Muddy silts graded into quartz sands and these again into silts. Consequently, divisions of such a series, made for the purpose of mapping and studying the structure of the region, are necessarily somewhat arbitrary. While a certain formation may consist mainly of white quartzite, it may also contain here and there beds of shale indistinguishable from beds that are the dominant feature of a different formation. The changes in the character of the sediments as they were laid down, moreover, were always more or less gradual, so that the divisional planes between formations are arbitrary and dependent rather on the judgment of the observer than on the recognition of any definite bed or parting.

In view of these facts, it is not surprising that the mapping of the various formations should be in many places exceedingly difficult and that some of the results should be uncertain. In the limited exposures available within the mines definite assignment of the country rock to one of the recognized formations is sometimes practically impossible.

Thus, although it will appear that the deposition of the lead-silver ores has taken place more extensively in rocks of certain types than in others, yet these types are found in various proportions in different formations and the geological distribution of the ores can be no more definitely described in terms of the arbitrary divisions known as formations than can the lithology of the sediments themselves.

It has been said that the principal lead-silver deposits occur in two areas, both of which are in the southern half of the district and in the part drained by the South Fork of Cœur d'Alene River. The position of these areas may be readily seen from fig. 3 (p. 84). The western one extends from Wardner northwestward beyond the boundary of the district as here mapped. Its demonstrated importance, however, rapidly diminishes in that direction and it is doubtful whether the area in which known profitable ore bodies occur should be extended much farther than is here shown, although there are indications of the presence of lead-silver ores for several miles west of Wardner. The deposits known to be of the first order of importance are all within a mile of Wardner and are worked in the Last Chance and Bunker Hill and Sullivan mines.

All the ore in these two mines lies in a fine-grained gray or greenish-gray sericitic quartzite which is assigned by Mr. Calkins to the Revett quartzite. Bedding planes are in few places conspicuous underground in the vicinity of the ore bodies owing partly to the thickness of the strata and partly to the prevalent jointing, shattering, and shearing which the brittle rock has undergone. The microscope shows that the grains of quartz are rarely over one-fifth of a millimeter in diameter, are rather ragged in outline, and are separated by much fine interstitial material consisting mainly of quartz and sericite with more or less secondary siderite.

The ores are probably in the lower part of the Revett formation, which is not very characteristically developed near Wardner and which in the rather complex folding and faulting of this part of the district, is distinguished with some difficulty from the underlying Burke rocks that form Haystack Peak and the slopes directly northwest of Wardner. (See Pl. XVIII, p. 154.) In the preliminary report on the district[a] it was stated that the Wardner ores occur in the Burke formation. Subsequent field work, however, has shown that this opinion was probably erroneous. The long adit of the Bunker Hill and Sullivan mine, with its portal about a mile west of Kellogg, is mainly in the Burke, but the section afforded by the tunnel (see p. 158) shows no definite change from this formation to the Revett quartzite.

The Senator Stewart mine, about a mile and a quarter northeast of Wardner, is in the Burke formation.

Between Wardner and Wallace the row of small argentiferous mines and prospects, including the Alhambra, Yankee Boy, Polaris, Chester, Nellie, and Argentine, are all in the Wallace formation, as may be seen from Pl. II (in pocket).

The important area of large lead-silver deposits northeast of Wallace, as outlined in fig. 3 (p. 84), is broadly heart-shaped. Within it are the Morning, Tiger-Poorman, Standard-Mammoth, Hercules, and Hecla mines, all of which are active producers. Other properties which are at present less important factors in the total production of the district are the Gold Hunter, Helena-Frisco, Granite, Custer, California, and Sixteen-to-One. These mines, as already stated, fall into three groups which may be designated (1) the Mullan mines, (2) the Canyon Creek mines, and (3) the Ninemile Creek mines. This grouping is merely one of convenience and topography and it is quite possible that future development may show that some ore bodies in one group are continuous, beneath the dividing ridge crests, with those in another.

The ore bodies of the Canyon Creek mines, including the Hercules, Tiger-Poorman, Hecla, Standard-Mammoth, and Helena-Frisco, are all within the Burke formation, which is typically developed in the vicinity of the town of Burke. The beds are folded at high angles and considerably faulted, so that it is not possible with our present knowledge to estimate the depth at which shafts would pass from this formation into the Prichard. This depth probably varies greatly for points only a short distance apart on the surface. In the Tiger-Poorman mine, the extreme southeastern part of the 1,200-foot level is in dark slate probably belonging to the Prichard formation, which has been upheaved by the O'Neil Gulch fault. There are lithological indications, moreover, that the 1,800-foot level of this mine is in rock very near the base of the Burke formation. None of the other Canyon Creek mines shows any indication of any approach to the Prichard formation. It should be noted, however, that the bottom of the Helena-Frisco mine could not be seen in 1904.

Owing to the structural complexity, poor surface exposures, and lack of sharp distinction in the various formations, the relations of the rocks in the vicinity of the Morning mine are not entirely clear. The surface rocks, as shown in Pls. II (in pocket) and XXII (p. 164), belong to the St. Regis and overlying Wallace formations. Some of the ore in the upper workings appears to have occurred in the St. Regis, but the stopes now worked are entirely in the Revett quartzite, which is the prevalent rock near the head of Grouse Gulch, west of the mine. In the vicinity of the ore bodies this quartzite has been strongly compressed and has acquired an irregular but pronounced slaty structure which causes it to resemble very closely the rocks of the Wallace formation. Further details as to the country rock of the Morning mine and the practical conclusions to be drawn from the occurrence of the ore in the Revett quartzite are presented in the description of the mine on pages 164 to 168.

The rock of the accessible workings of the Gold Hunter mine is a pale greenish-gray sericitic slate, much of which has a waxy appearance. It resembles the schistose Revett quartzite of the Morning mine, which, however, is more gritty and does not effervesce with acid as does the

[a] Ransome, F. L., Ore deposits of the Cœur d'Alene district, Idaho: Bull. U. S. Geol. Survey No. 260, 1905, pp. 274-303.

calcareous Gold Hunter rock. The latter, indeed, has all the characteristics of the Wallace formation but according to the work of Mr. Calkins it must be considered part of the St. Regis. This example well illustrates the difficulty that besets one who in this region attempts to get his geological bearings underground. Both the St. Regis and the Wallace formations contain certain beds that are lithologically identical and underground workings are not as a rule extensive enough to enable the observer to determine whether the visible rock is the subordinate and exceptional or the dominant and characteristic rock of the formation.

Whether the Gold Hunter mine is really in the Wallace or in the St. Regis formation is perhaps a question still open to some difference of opinion, but the essential and determined fact, from an economic standpoint, is that in either case the ore occurs at a higher stratigraphic horizon than that of the Morning mine. Surface relations, as shown in Pl. XXII (p. 164), indicate that the rich ore of the upper tunnels occurs in a narrow strip of Revett quartzite. The structural relations of this strip to the St. Regis rocks which bound it on the south and occur in the lower workings of the mine are not clear.

Of the Ninemile Creek group of mines, the Custer, on Custer Peak, is apparently in rocks near the base of the Burke formation, possibly in part Prichard. The rock of the Granite mine is probably also near the line between the Prichard and Burke formations. It is mapped as Prichard by Mr. Calkins, but as it is much metamorphosed and contains some quartzite the possibility of its belonging to the basal part of the Burke can not be quite eliminated. The Sixteen-to-One mine is somewhat more certainly in the Prichard slate.

The ore of the California mine, near Bradyville, is in white quartzite assigned by Mr. Calkins to the Revett formation. As mapped by him (see Pl. II, in pocket), this is a fault block surrounded by rocks of the St. Regis formation.

Northeast of Sunset Peak are several prospects or small mines not yet producing ore at a profit. Among these may be mentioned the Monarch (Barton), Paragon, and Bear Top mines. All of these are in the upper part of the Prichard formation, where beds of quartzite alternate with those of dark slate and the formation shows the transitional character found near the base of the overlying Burke. Nearly all of the ore in these deposits occurs in the quartzitic beds.

The geological or formational distribution of the lead-silver ores, so far as it can be determined, is summed up in the following table:

*Distribution of lead-silver ores of Cœur d'Alene district, by formations.*

| Formation. | Mines. | Approximate percentage of total lead output in 1905. |
|---|---|---|
| Striped Peak | None | |
| Wallace | Yankee Boy, Polaris, Argentine, etc | |
| St. Regis | Gold Hunter and upper tunnels of Morning | 0.7 |
| Revett | Bunker Hill and Sullivan, Last Chance, Morning, California, and upper tunnels of Gold Hunter | 60.1 |
| Burke | Standard-Mammoth, Tiger-Poorman, Hercules, Hecla, Helena-Frisco. Custer | 39.0 |
| Prichard | Granite, Sixteen-to-One, Paragon, Barton, etc | .2 |
| | | 100.0 |

It appears from the foregoing table that over 99 per cent of the lead (and approximately the same proportion of silver) produced in the Cœur d'Alene district comes from the Revett and Burke formations, both of which are composed principally of fine-grained, more or less sericitic quartzites. The rock most favorable to the formation of large bodies of lead-silver ore is undoubtedly a fine-grained sericitic quartzite in which the quartz grains instead of closely interlocking are separated, as shown in Pl. IX, *A* (p. 96), by considerable interstitial material, largely sericite. A large part of the Revett quartzite, however, is not particularly sericitic and has grains that interlock after the manner of typical quartzite. Such rock seems to be less favorable to the deposition of lead-silver ore than the more sericitic variety, which, while not perhaps the most characteristic part of the formation, is very abundant, particularly in the lower beds. Even in those deposits which occur in the Prichard formation, it is noteworthy that the quartzitic beds are the ore bearers and that nearly all the prospects are in the upper part of the Prichard, in beds that partake of the character of the overlying Burke formation.

In conclusion it may be pointed out that mines now in the Revett formation have a presumptive advantage over those in the Burke, inasmuch as they are likely to have a much greater thickness of beds favorable to ore deposition between their bottom workings and the top of the Prichard slate.

Character of rock is obviously not the only influence that has determined the areal distribution of the ores. The district, as may be seen from Pl. II (in pocket), contains large areas of Revett and Burke rocks which so far as known are not ore bearing. Such an area, for example, is that south of the North Fork of the Cœur d'Alene, below the mouth of Beaver Creek. This part of the district exhibits practically no mineralization, although it must be said that it has received less attention than more accessible portions. Were the Canyon Creek and Ninemile Creek mines the only ones in the district, mineralization might be ascribed to the monzonitic intrusions in their vicinity. The Mullan mines, however, are 3 miles and the Wardner mines 7 miles from the nearest exposures of monzonite or syenite, so that the truth of the hypothesis that there is some connection between these intrusions and ore deposition is not at once obvious. The unmineralized areas are in general less complex in structure than those in which occur the large ore bodies, but the difference in the degree of folding and faulting is certainly not nearly so marked as the contrast in productiveness.

## THE ORES.

### MINERALOGICAL CHARACTER.

#### CONSTITUENTS.

The essential constituent of all of the unoxidized lead-silver ore is a fine to medium grained massive galena which is always argentiferous, although the ratio of lead to silver varies in different mines. In 1903 the Hercules mine produced in round numbers 12,000,000 pounds of lead and 860,000 ounces of silver. This corresponds to about one part of silver by weight to 200 parts of lead. The crude sulphide ore from this mine was said in 1904 to average 50 per cent lead and 45 ounces of silver to the ton, which would give approximately one part of silver to each 300 parts of lead. In most of the mines the proportion of silver is lower than this and the figures given, taken in connection with the fact that a pound of lead brings the miners about 4 cents while the same weight of silver is worth approximately $7, show that the actual proportion of silver present in the galena need not be high in order to greatly increase the value of the ore. On the other hand, 1 per cent per ton, or a "unit" of lead, was worth, at the commercial price of lead (4.35 cents a pound) in 1904, 87 cents, while an ounce of silver was worth 58 cents. The concentrates as a rule contain from 25 to 50 cents in gold to the ton.

In a few of the mines the galena occurs so nearly pure that it can be sorted by hand and shipped in lumps. Such is the case in the Hercules, Bunker Hill and Sullivan, Last Chance, and Hecla mines. But with the exception of the Hercules, the quantity of ore thus sorted forms a very small part of the output of the large mines. As a rule the galena is mixed with other sulphides and gangue to such an extent that crushing and concentration are necessary to fit the product for market.

The sulphides associated with the galena include pyrite, pyrrhotite, chalcopyrite, and sphalerite. The copper sulphantimonite, tetrahedrite, is found sparingly distributed through most of the deposits and its presence invariably indicates an ore rich in silver. The sulphide of antimony, stibnite, and possibly the rare sulphantimonite of copper, chalcostibite, are exceptional rather than characteristic minerals of the lead-silver ores.

Not all the minerals just mentioned occur in each deposit and their relative abundance varies greatly in different parts of the district. In the large mines near Wardner sphalerite is never a conspicuous constituent of the ore, much of which is apparently free from zinc. Chalcopyrite, though not unknown, is decidedly rare and tetrahedrite occurs only in small sporadic bunches in some of the richer stopes. Pyrrhotite is unknown in this part of the district, while it is comparatively abundant in the lowest level of the Tiger-Poorman mine, near the 850-foot level of the Standard-Mammoth mine, and in the Helena-Frisco and Sixteen-to-One mines. The presence of much pyrite is in most cases a sign of low-grade ore. The mineral is hardly noticeable in the best ore from the Wardner mines but is comparatively abundant in the Gold Hunter, Morning, and Helena-Frisco mines, in all of which the average tenor of the ore is low. In general, quartz and pyrite exhibit a characteristic affinity, and siderite and galena are similarly related. Thus low-grade ore is usually (not always) quartzose and pyritic, while rich ore consists chiefly of galena and siderite. In the Jersey ore bodies of the Last Chance mine, however, quartz is fairly abundant as a gangue mineral with high-grade ore. In the Hercules mine, also, siderite is practically absent, the subordinate gangue of the rich ore being chiefly quartz.

In most of the ore bodies near Wardner siderite is the principal gangue mineral, and a very large part of the Bunker Hill and Sullivan ore consists of a mixture of galena and siderite with only traces of other constituents. In the richest ore the galena predominates and forms irregular and ill-defined bunches. These grade into massive siderite in which the galena forms countless small reticulating veinlets. Although many of the veinlets are of microscopic width, the absence of definite walls to the little fissures is noticeable and it is evident, even without the use of the microscope, that the galena has not merely filled the cracks but has been deposited metasomatically at the expense of the siderite. At the intersections of the cracks the galena has gathered in little bunches. In a more advanced stage of replacement the veinlets are wider and more irregular, the bunches of galena at the intersections are larger, and the final stage of the process is a mass of nearly solid galena with perhaps here and there a small shadowy remnant of siderite. In the other direction, from the center of a rich mass outward, the siderite with its network of stringers and bunches of galena passes into material in which the lead sulphide is less abundant and in which residual masses of sericitic quartzite appear. This in turn grades into the ordinary quartzitic country rock, containing irregular veinlets, ill-defined bunches, and scattered microscopic crystals of siderite with finely disseminated pyrite and in some places veinlets of white quartz carrying a little valueless pyrite.

It thus appears, as will be more fully shown in the following section on paragenesis, that although this ore in general is a metasomatic replacement of quartzite by siderite and galena the process is actually more complex than that statement would imply, and has taken place in at least two steps. The siderite has first replaced the quartzite and the galena has then attacked the siderite. That galena, however, can under some conditions directly replace the sericitic quartzites of the region is amply illustrated in these same Wardner mines, as well as in those in other parts of the district.

Not all the ore of the Wardner mines is of the type just described. In the ore bodies of the Skookum or Jersey fissure zone, which, as more fully explained on pages 160–161, is a branch from the main ore zone of the Bunker Hill and Sullivan mine and has furnished much of the ore of the Last Chance mine, siderite, although abundant, is not quite so prominent or exclusive a gangue as elsewhere in these mines. A considerable part of the Jersey ore consists of comparatively coarse granular galena in which are embedded rounded isolated crystals of quartz several inches in length. The galena is also in many places associated with bunches of massive white quartz. Much of this ore is apparently younger than the replacement ore just described and clearly has been deposited partly in open fissures. It is in many places very closely associated with sideritic ore of metasomatic origin and the difference in age of the two varieties is probably not great. The questions suggested by the appearance in these ores of more than one generation of the principal constituents will be more fully discussed in the section devoted to ore genesis (pp. 134–140).

The ore of the Jersey fissure zone contains more tetrahedrite than the ore associated with the main Bunker Hill zone and is comparatively rich in silver. It is commonly stated by those familiar with the Wardner mines that the fine-grained, so-called "steel galena," which in many places is clearly the result of crushing and recrystallization of coarser galena along recent fissures, is richer in silver than the rest of the ore.

There is no very sharp distinction possible between what may be called the Wardner type of ore, consisting predominantly of galena and siderite, and the ores found in the mines near Mullan. The Morning mine, for example, contains some ore that is not essentially different from the medium-grade ore of the Bunker Hill and Sullivan mine, in which siderite is traversed by a network of veinlets of galena. On the whole, however, the Mullan ores are of lower grade. They contain less siderite and more quartz, as well as a greater proportion of country rock. Sphalerite and pyrite are more abundant, and magnetite, not known at Wardner, has been recognized in the concentrates from the Morning mine. Some of the best ore in the Gold Hunter mine consists of galena, with a little sphalerite, pyrite, and probably tetrahedrite, in a gangue of barite. This ore, which has a pronounced banded structure, is exceptional, nothing resembling it being known in the other mines.

The ores of the Canyon Creek mines exhibit as much diversity as is to be found in the lead-silver deposits of the whole district. Siderite on the whole is much less abundant than at Wardner and in the Hecla mine was noted only as a microscopic constituent. It is also decidedly subordinate to quartz as a gangue mineral in the Helena-Frisco mine. Sphalerite is fairly abundant. Chalcopyrite occurs in small quantities in the ores of the Hercules, Tiger-Poorman, and Helena-Frisco mines and in moderate abundance in certain parts of the Standard-Mammoth mine. None has been recognized, however, in the Hecla. Pyrrhotite, although present in the Highland Chief prospect southwest of Kellogg Peak, has not been recognized at Wardner or Mullan but is found in considerable quantities in the lower levels of the Tiger-Poorman and Standard-Mammoth mines, and is a minor constituent of the Helena-Frisco ore. Tetrahedrite is very rare in the Canyon Creek group, although a similar gray sulphantimonite of copper, supposed to be chalcostibite, occurs sparingly in the Standard-Mammoth mine.

The ore of the Granite mine on Ninemile Creek is very different in character from that of the Bunker Hill and Sullivan mine. It consists of galena and abundant sphalerite, the latter in some parts of the deposit being the principal sulphide. A little chalcopyrite occurs, and pyrrhotite, though not visible in any of the specimens collected, is probably not entirely absent, for it occurs in the somewhat similar ore of the Sixteen-to-One mine. Much of the ore when coarsely pulverized is attracted by a weak magnet, and thin sections show that this property is due to the presence of magnetite which is intergrown with the sphalerite. Siderite is not known in the Granite mine. The prevailing gangue is a highly metamorphosed quartzite crowded with minute crystals of garnet, pyroxene, biotite, and muscovite. Where the pyroxene predominates the quartzite is green; but the preponderance of garnet gives a pink tint to the rock. A little quartz and microscopic crystals of some carbonate, probably calcite, are the only other gangue minerals seen.

The sulphides are intimately associated with the metamorphic silicates, irregular bunches of ore, which have clearly formed by replacement of the quartzite, showing in some places an outward gradation from galena to sphalerite, magnetite, and pyrite, and from these minerals to garnet, pyroxene, and quartz. (See Pl. X, *C*, p. 98.)

The contrast between such a deposit as that of the Granite mine, with its characteristic contact-metamorphic features, and the galena-siderite bodies of the Bunker Hill and Sullivan mine is striking and at first glance suggests that the two kinds of deposit are genetically distinct. Yet careful study of the whole district modifies this first impression. The ores of the Custer and Helena-Frisco mines, which are also in part associated with metamorphic silicates, supply a link between the ores of the Granite and Sixteen-to-One mines and those of the Canyon Creek mines, while the occurrence of pyrrhotite in the Tiger-Poorman and Standard-Mammoth mines and in the Highland Chief prospect south of Wardner, as well as the presence of magnetite in the Morning ore, suggests that sharp mineralogical distinction between the ores of Ninemile Creek and those of Wardner would be difficult if not impossible.

With the lead-silver ores should probably be considered those of the small and not hitherto very profitable mines lying in the green slaty rocks of the Wallace formation between Wallace and Wardner, although such ore as has been found in these deposits is much more valuable for silver than for lead. In the Polaris mine, one of the oldest and best known of these properties,

# PLATE XIII.

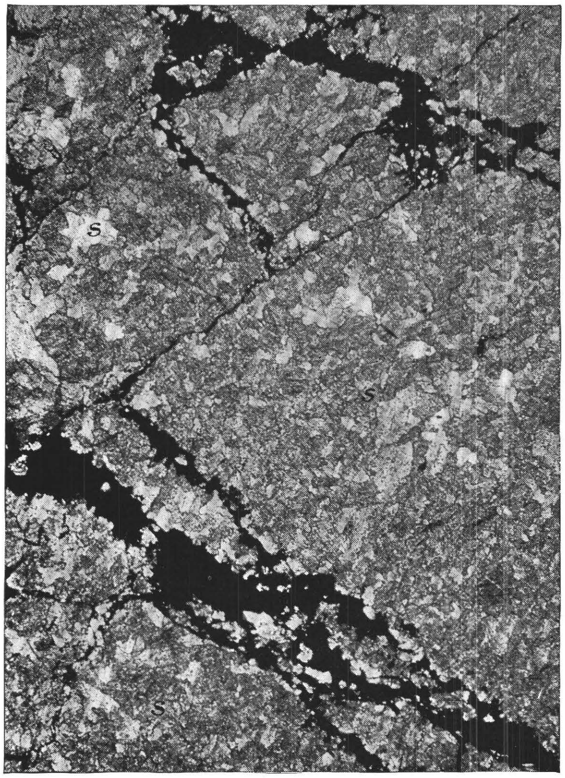
## Photomicrographs of Ores.

*A*. Lean ore (I 34) from the Bunker Hill and Sullivan mine, showing incipient mineralization by galena (black) along cracks in siderite (*s*). Magnified 30 diameters. Ordinary light.

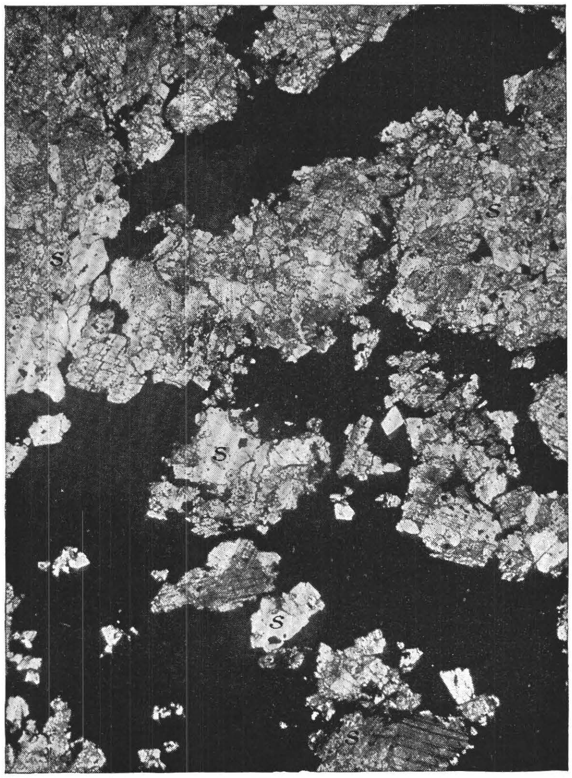
*B*. Ore (I 5) from the Bunker Hill and Sullivan mine, showing more advanced stage of mineralization by galena (black) in siderite (*s*). Magnified 30 diameters. Ordinary light.

*C*. Gangue of ore (I 61) from the Last Chance mine, showing replacement of quartzite (*q*) by siderite (*s*). Magnified 40 diameters. Nicols crossed.

*D*. Ore (I 47) from the Last Chance mine, showing development of galena (black) and a second generation of siderite (*s'*) in older siderite (*s*). Magnified 30 diameters. Ordinary light.

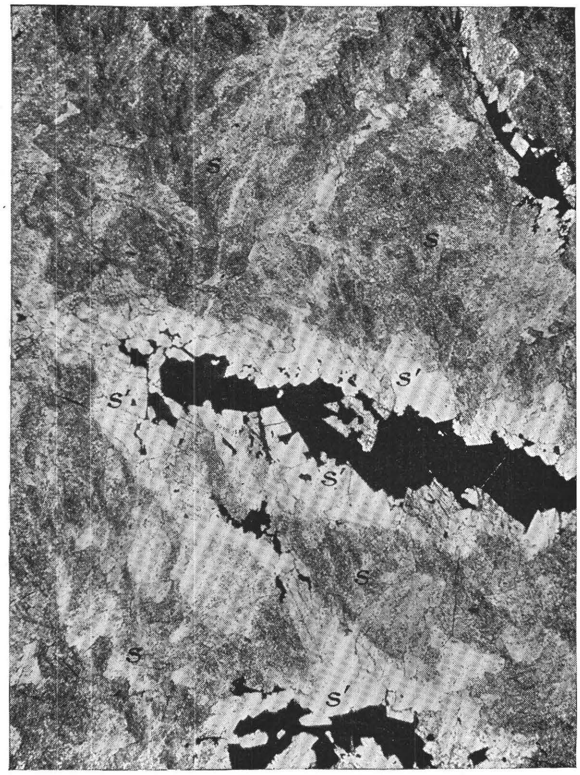



*A*




*B*


*C*




*D*

PHOTOMICROGRAPHS OF ORES.

the ore consists of arsenical tetrahedrite, pyrite, and a little galena in a siderite and quartz gangue. The shipping ore is said to carry about 180 ounces of silver to the ton, 10 per cent of copper, and up to 8 per cent of lead. The Yankee Boy mine, on Big Creek, just over the ridge from the Polaris, is of similar character and contains a little proustite. The Chester, Nellie, Argentine, and other mines in this belt were idle in 1904 and no specimens of their ores were seen. The dump of the Argentine, which is said to have shipped 500 tons of ore carrying up to 20 ounces to the ton in silver, shows very abundant siderite and quartz without much sulphides. In general, the ores of this so-called dry belt seem to occur in small but highly argentiferous bunches or streaks in which tetrahedrite is a more important constituent than galena.

In the Sixteen-to-One mine and in several small lead-silver mines or prospects in the Murray region the ore occurs in the Prichard formation. The dark slates of this terrane are less readily replaced by ore than the quartzitic rocks of the Burke formation and the ore masses are smaller. The ore consists of galena with much less siderite than is found in the mines near Burke, Mullan, and Wardner, such gangue minerals as are present being mainly quartz and calcite. Sphalerite is common and there is generally a little chalcopyrite visible. In the Sixteen-to-One mine, as already mentioned, the galena is associated with pyrrhotite, garnet, pyroxene, and biotite.

The minerals of the lead-silver ores are as a rule irregularly intergrown and in consequence are seldom bounded by crystal faces. Moreover, with the exception of the reticulation of siderite by veinlets of galena in the Bunker Hill and Sullivan, Last Chance, and, to a less extent, in the Morning mine; a somewhat irregular banding of some of the ore on the third level of the Last Chance mine; and the narrow banding of sulphides with barite in the Gold Hunter mine, the ores exhibit no definite or regular structure.

The principal valuable constituents of the oxidized ore are cerusite and native silver. Cerargyrite, or some other halogen compound of silver, is probably present in some of the richer ores, although not, so far as known, in visible crystals or aggregates. These minerals are invariably accompanied by more or less limonite, which results from the decomposition of siderite as well as of pyrite. Thus the oxidized ore is commonly a porous, crumbling, rusty mass, partly held together by massive cerusite and residual stringers of quartz and containing nests or vugs of characteristically striated crystals of cerusite. Massicot, the earthy yellow oxide of lead, is an important constituent of some ores, particularly those in the upper levels of the Hercules mine, and pyromorphite is present in small quantities in some deposits. Plattnerite has been found only in the You Like ore body of the Morning mine. The green and blue carbonates of copper are found sparingly in oxidized ore derived from bodies originally containing a little chalcopyrite or tetrahedrite. The entire absence, so far as known, of the sulphate of lead from the oxidized ores of the Cœur d'Alene district is noteworthy and shows that carbonic acid, doubtless largely derived from siderite, has been a more effective reagent than the probably smaller quantity of sulphuric acid formed by oxidation of the sulphides. Covellite was observed as an alteration product of chalcopyrite in partly oxidized ore in the Last Chance and may occur sparingly in other mines in the district. It occurs as a soft sooty material that does not attract attention unless present in some quantity.

## PARAGENESIS.

By paragenesis is meant the association of the various ore and gangue minerals with special reference to the order and mode of their formation.

While the careful study of the paragenesis of the minerals in a group of metalliferous deposits is important and may throw much light on the genesis of the ores, yet it can not be safely premised that the various minerals have formed in a simple nonrecurrent sequence, that the order of deposition found at any one place is common to all similar deposits in the same district, or that the most thorough observations will necessarily be rewarded by the discovery of even a somewhat complex and recurrent order of formation. Many large ore bodies record something more than a simple succession of a few distinct events. Their development has been a complex process involving repeated movements of the rocks, successive fissuring of materials earlier deposited, and several periods of crystallization for the same minerals. A large part of scientific progress has come from the reduction of the apparently complex to the actually simple, but whether in the interpretation of ore deposits this tendency toward simplification makes equally for truth may fairly be questioned. It is doubtful whether the literature of economic geology sufficiently recognizes or emphasizes the length of time and the many mechanical and chemical steps involved in the accumulation of most large ore bodies.

In the Cœur d'Alene region the order in which the various mineral constituents of the ores have been deposited can not always be readily determined, as the ore is prevailingly massive and successive crusts of one mineral upon another are practically unknown. In general, siderite seems to have been one of the earliest of the minerals to form and in those deposits where it is abundant it replaced the quartzitic country rock to a considerable extent before the sulphides began to crystallize. The latter, particularly the galena, in turn replaced the siderite as described on page 108, such replacement as a rule being accompanied by continued deposition of siderite. At one place in the Bunker Hill and Sullivan mine a veinlet of siderite was observed that was distinctly younger than some very fine-grained galena which it traversed. It thus appears that the formation of siderite was not restricted to the initial stage of ore deposition. In many ores galena, sphalerite, pyrite, chalcopyrite, siderite and quartz were synchronously deposited, and in some deposits barite and tetrahedrite should be added to this list. There is abundant evidence, however, that quartz has formed at different periods. In the Wardner mines and in the Standard-Mammoth mine the ore is traversed by stringers of younger quartz. In the Last Chance mine, at Wardner, moreover, some of the quartz is cut by veins of galena. As the galena in this mine has crystallized with quartz also, these relations indicate at least three periods of quartzose deposition during the accumulation of the ore.

The galena also is not all of one generation, as is shown by the occurrence of veinlets of fine-grained galena in more coarsely crystalline varieties in the Last Chance and other mines. Tetrahedrite, chalcopyrite, and pyrrhotite appear to be everywhere primary minerals of the same age as the galena with which they are associated. In the Standard-Mammoth mine, however, chalcostibite (?) associated with a little galena occurs in stringers of quartz which cut the main mass of the ore.

In deposits such as those of the Granite mine, which are characterized by contact-metamorphic features, many individual ore bodies show a gradual change from a central mass of ore consisting largely of galena, through a zone in which sphalerite and magnetite or pyrrhotite predominate into country rock in which the sulphides and magnetite are subordinate to quartz, garnet, biotite, and pyroxene. Although the sulphides may possibly be in part younger than the metamorphic silicates, yet there is no completely satisfactory evidence of this and it is quite clear that in certain parts of the deposits magnetite, sulphides, and silicates have all formed at the same time.

Although the mineralogical character of the large lead-silver deposits exhibits great uniformity, some of the ore bodies are known to change their composition with increase of depth, as is more fully described on page 130. No evidence has been found, however, that in any way connects the observed changes with the descent of solutions from the zone of oxidation. Such variations as occur are apparently original and not due to secondary enrichment from above.

In the process of oxidation cerusite develops from galena without any visible intermediate product. The change is not a direct replacement of the sulphur of carbonic anhydride, but the galena is irregularly corroded by the oxidizing solutions and cerusite crystals are deposited in the cavities thus formed. In other words, the lead itself is somewhat mobile during the change from sulphide to carbonate. The various minerals of the oxidized ores are still forming and make up soft earthy masses in which no sequence of crystallization is apparent. It is not known, for example, whether pyromorphite, like cerusite, forms directly from galena or whether it is derived from some oxysalt of lead.

The small quantity of sphalerite formerly in the ores which have undergone oxidation has left no recognizable trace of its presence. The hydrous zinc sulphate goslarite is highly soluble and may have been carried off in solution and dispersed through the country rock.

## TENOR.

Some shipping ore in the Cœur d'Alene district carries as much as 55 per cent of lead, but the concentrating ores, which furnish the bulk of the output, range from about 3 to 14 per cent of lead and from 2.5 to 6 ounces of silver to the ton. These are concentrated to a product containing approximately 50 per cent of lead. The average proportion of silver in the ores is a little over half an ounce to each unit of lead, that is, ore carrying 10 per cent of lead will ordinarily contain 5 to 6 ounces of silver to the ton. The ores of the various mines, however, exhibit a considerable range in tenor. The gold, even in concentrates, rarely exceeds 50 cents (0.025 ounce) to the ton.

During the fiscal year 1903–4 the ore of the Bunker Hill and Sullivan mine averaged 8.8 per cent of lead and 3.9 ounces of silver. Some of the best ore being stoped in this mine in 1904 carried about 25 per cent of lead and from 12 to 15 ounces of silver. During the calendar year 1905 the ore from the same mine (342,414 tons) averaged 13.3 per cent of lead and 6.2 ounces of silver. The average of the Last Chance ore from the earliest complete records to the end of 1904 is approximately 10 per cent of lead and 4 ounces of silver. The ore of the Morning mine in 1903 had an average tenor of 7.4 per cent of lead and 2.9 ounces of silver to the ton. That of the Helena-Frisco for the same year was 4.5 per cent of lead and 2.7 ounces of silver. This ore, however, yielded no profit. The average for this mine in 1897 was 5.5 per cent of lead and 4.2 ounces of silver.

The Tiger-Poorman mine during the last few years has yielded a low-grade ore from which profit is won by careful and economical mining. In 1904 the ore from this property averaged 5.5 per cent of lead and 2.7 ounces of silver, and was probably as low in tenor as any other successfully worked in the district. The neighboring Hecla mine produced in 1905 nearly 100,000 tons of ore averaging 9.2 per cent of lead and 8 ounces of silver.

The Standard-Mammoth ore in 1904 averaged approximately 6 per cent of lead and 5 ounces of silver. In 1903 the ore of the Gold Hunter mine averaged 4 per cent of lead and 4.2 ounces of silver, while returns for 1904 and 1905 show only 3 per cent of lead and 3.3 ounces of silver. Such ore scarcely yields a profit in this district. If the average commercial price of lead in 1904 be taken as 4.35 cents a pound and of silver as 58 cents a fine ounce, then a unit of lead would be worth 87 cents and ore from the Gold Hunter mine in that year would have a gross value of $4.52 a ton, as against $4 ore (4.6 per cent lead), which is about as low as can be profitably worked in the soft-lead districts of southeastern Missouri.

The only important mine shipping crude ore alone in 1904 was the Hercules, which was producing from 1,000 to 1,200 tons a month of ore carrying approximately 50 per cent of lead and 45 ounces of silver.

For convenience of comparison the averages for the principal mines, with the approximate ratios of concentration and the average contents of the concentrates, are brought together in the following table. The ore in each mine, as has been shown, varies considerably from year to year, so that the figures given in the table are at best approximations. Unless otherwise noted, they are based on the total tonnage and metal production of each mine for a whole year, as furnished by each company.

*Average tenor of ore of the principal mines in the Cœur d'Alene district.*

| Name of mine. | Ore. | | Approximate ratio of concentration. | Concentrates. | | Period. |
|---|---|---|---|---|---|---|
| | Percentage of lead. | Ounces of silver per ton. | | Percentage of lead. | Ounces of silver per ton. | |
| Bunker Hill and Sullivan | 13.3 | 3.9 | 7.5:1 | 55 | 19.5 | Year 1905. |
| Last Chance | 10 | 4 | 5 :1 | 50 | 20 | From earliest record to end of 1904.[a] |
| Morning | 7.4 | 2.9 | 7 :1 | 50 | 16 | Year 1904. |
| Gold Hunter | 3 | 3.3 | [b] 16 :1 | 50 | 55 | Year 1905. |
| Hercules | 50 | 45 | Hand-sorted ore. | | | Year 1904. |
| Tiger-Poorman | 5.5 | 2.7 | 10 :1 | 55 | 27 | Do. |
| Hecla | 9.2 | 5.8 | 5.5:1 | 50 | 30 | Year 1905. |
| Standard-Mammoth | 6 | 5 | 8.5:1 | 50 | 41 | Year 1904. |
| Helena-Frisco | 9.2 | 5.8 | 5.5:1 | 47 | 28 | Year 1903. |

[a] Approximate figures in 1904.
[b] Ratio assumed to give the usual 50 per cent of lead to which concentrates are raised in this district.

Ores unusually rich in silver were formerly mined in the Sierra Nevada and Crown Point mines, west of Wardner. The Sierra Nevada ore in 1887 carried 47 per cent of lead and from 60 to 90 ounces of silver to the ton. Over 3,000 tons of ore that carried over 80 ounces of silver a ton and up to 65 per cent of lead were shipped from the Crown Point mine prior to 1903. This, like the Sierra Nevada ore, was partly oxidized. Some of the oxidized ore of the Hercules mine contains as much as 150 ounces of silver to the ton, according to Manager H. L. Day. Lessees working in the No. 1 tunnel of the Gold Hunter mine in 1904 reported that assays of the best galena and tetrahedrite ore, as sorted for shipment, showed 53 per cent of lead and 140 ounces of silver to the ton. Some of the partly oxidized ore being taken by lessees from the No. 2 Standard-Mammoth tunnel in the same year was also rich, carrying over 70 per cent of lead and up to 170 ounces of silver.[a] Small bunches of tetrahedrite ore found near the surface in the Alice, a prospect in Ruddy Gulch, west of Mullan, were said by Mr. John Foss, superintendent and part owner, to have carried up to 300 ounces of silver to the ton and an appreciable quantity of gold.

The ore of the small mines in the Wallace formation, between Wallace and Wardner, is also much higher in silver than the typical lead-silver ore of the large deposits. The shipping ore from the Polaris mine is said to contain 180 ounces of silver to the ton, 10 per cent of copper, and up to 8 per cent of lead. The tenor of the Yankee Boy ore is not known, but the presence of tetrahedrite and proustite indicates that silver is a much more important constituent than lead. The Argentine ore, of which about 500 tons were shipped, carried up to 20 ounces of silver.

## FORM AND STRUCTURE OF THE DEPOSITS.

### GENERAL CHARACTER.

Most of the lead-silver ores of the Cœur d'Alene district occur in what are commonly termed metasomatic fissure veins.[b] They are generally tabular deposits, formed partly by the filling of open spaces, but largely by replacement, along nearly vertical zones of fissuring or of combined fissuring and shearing, the latter term being taken to mean a tangential movement resulting usually in a zone of mashing or schistosity without the development of visible open fissures. Inasmuch as the term *vein* is strictly applicable only to those deposits that fill or accompany a comparatively simple fissure, it is perhaps more correct to refer to the Cœur d'Alene deposits in general under the broader name *lode*. Each occupies a zone of fissuring rather than a single fissure.

The type is best exemplified by the Canyon Creek and Mullan groups of mines. The deposits worked in the mines at Wardner are very different in form from those of Canyon Creek and Mullan, although, broadly regarded, they fall into the same class. The ore bodies of the Granite mine also present some exceptional features that will be adverted to later. (See p. 127.) The general strike of the lodes is northwesterly. In the Canyon Creek and Mullan

[a] Apparently reliable statement by lessee.
[b] Lindgren, W., Metasomatic processes in fissure veins: Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 680.

group the prevailing strike is about N. 70° W., with local variations from N. 45° W. to west. At Wardner the Bunker Hill and Sullivan-Last Chance lode strikes N. 42° to 45° W. With the exception of this lode, which dips 38° SW., and the Sierra Nevada lode, which in places is almost horizontal, the lodes are nearly vertical. The Standard-Mammoth and Hecla dip north-northeast at about 85°. The Tiger-Poorman, Hercules, and Helena-Frisco have generally south-southwest dips ranging from 75° to nearly vertical; the Morning and Gold Hunter lodes are practically vertical.

Though the fissures appear to have been opened originally by faulting, the displacement is in no case measurable, and there is usually no observable difference in the rock on each side of the fissure. The region, as has been shown by Mr. Calkins, is by no means destitute of important faults that have left their mark on the geological structure (see Pl. II, in pocket); but these structurally important faults are not ore bearing.

A few of the productive fissures are simple fractures. More commonly, however, they exhibit various kinds of complexity, as will presently be more fully described.

The pay shoots vary widely in form. In some deposits, particularly in those of narrow, veinlike character, pay shoot and fissure zone may be practically coextensive. In others, where the zone of fissuring is so wide that the deposit can be called a lode only by somewhat extending the ordinary usage of the term, the pay shoots may be irregular both in distribution and in shape and may be separated from one another by barren, fissured, or shattered quartzite. The relative importance of the processes of fissure filling and rock replacement has not been the same in all deposits, so that the sharpness or regularity of the boundaries between ore and country rock also varies in different mines.

### DIRECTIONS OF FISSURING.

For purposes of comparison the principal fissures in which, or associated with which, the ores occur are plotted on the same scale and exhibited in plan in fig. 5. Only those fissures developed in any one mine, or in a connected group of workings, are shown in their proper relative positions, the others being grouped merely for convenience of illustration.

It is clear from this figure that the fissures are irregularly curved and that their strikes can not be discussed as if the trace of each lode on a horizontal plane were a straight line. In spite of irregularities, however, they show a rather remarkable general agreement in trend, the courses of nearly all lying between west and northwest or east and southeast. The regular Hecla lode strikes practically northwest and southeast. The part of the Bunker Hill fissure west of Milo Creek strikes in general a few degrees north of northwest, but the part east of Milo Creek, on the Sullivan claim, strikes nearly west-northwest. The Gold Hunter, Custer, Morning, and Tiger-Poorman lodes strike west-northwest. The Standard-Mammoth and You Like lodes have general strikes only 10° or 15° north of west. The Helena-Frisco has really three lodes; the Black Bear runs nearly east and west, the Frisco about 20° north of west, and the Gem, a curved irregular lode, has a general strike about 15° south of west. The last is the only lead-silver lode of consequence known in the district that strikes south of west or north of east. No definite statement is permissible as to the Hercules lode, but it is evident from the surface relations that it has the general west-northwest trend of most of the Canyon Creek deposits.

The dips of the ore-bearing fissures are more variable than the strikes. In most of them the dip is nearly vertical, the Bunker Hill fissure, with an average dip of about 38° SW., and the curved, blanket-like Sierra Nevada and Silver King deposits being notable exceptions to the general rule. The Tiger-Poorman, Custer, and Gold Hunter lodes all dip at angles, ranging from 75° SW. to 90°. The Standard-Mammoth, Hecla, Morning, and You Like lodes have equally steep dips to the northeast. For a depth of 1,800 feet the Frisco lode dips from 80° to 85° SW. Below the 1,800-foot level the dip apparently changes to the northeast. The Black Bear lode is practically vertical. The Gem lode, while short and irregular, has a general dip to the south of about 70°.

## MOVEMENT ALONG THE PRODUCTIVE FISSURES.

The formation of the fissures was undoubtedly accompanied in most cases by an appreciable slipping of one wall past the other, and it is probable that in some places this movement constituted a fault of considerable throw. In some mines there is evidence that the motion has continued and is in part later than the ore. None of the ore-bearing fissure zones, however, appears as a structurally important fault. Nowhere, so far as present underground workings show, has the displacement been sufficient to bring about, by the juxtaposition of different formations, any recognizable difference in the foot and hanging walls of a lode, nor do any of the lodes appear as faults on the geological map (Pl. II, in pocket). It must be said, however, that in thick formations of like lithological character the recognition and measurement of minor faulting is exceedingly difficult.

The Bunker Hill fissure, to which the Wardner ore deposits are intimately related, has the appearance of being a considerable fault. The plane of maximum movement is marked by a tough, nearly black clay gouge from 1 inch to 2 inches in thickness. Immediately under the

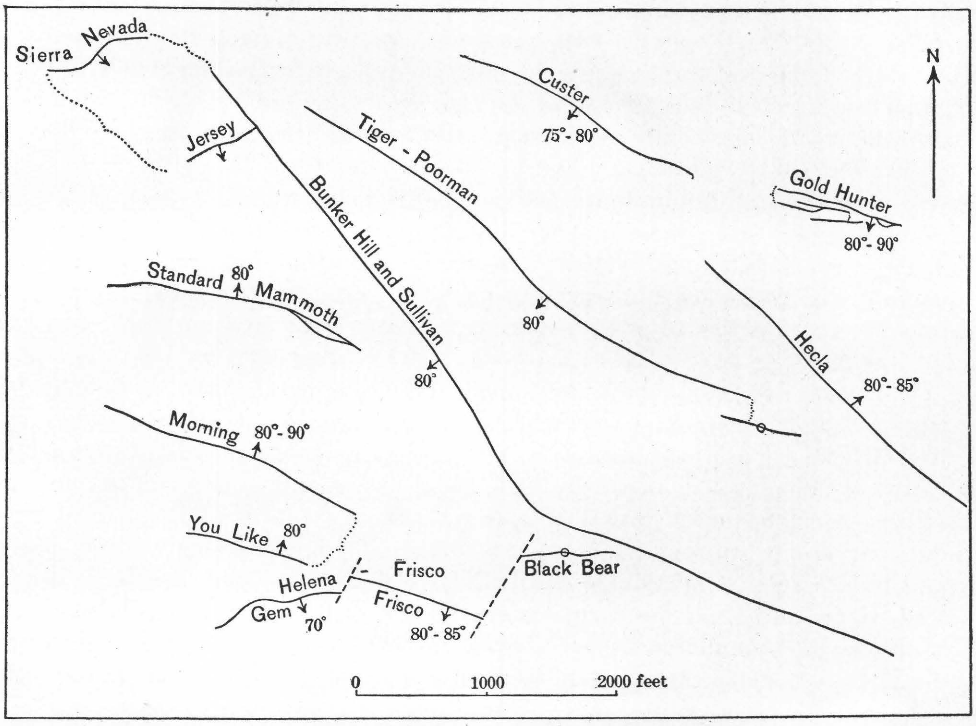



Fig. 5.—Diagram showing trends of principal lead-silver lodes. Only those connected by brackets are shown in true relative positions.

gouge, in the foot wall, is a white, creamy, or buff band which ranges in thickness from a few inches to a foot or more. This band is composed of crushed quartzite, the crushing in some places being so complete as to have produced a white, sugary powder. The contrast between the dark seam of gouge, which owes its color in part to the presence of finely triturated galena and minute crystals of pyrite, and the white crushed quartzite is striking and usually serves to distinguish this fissure from others that might be confused with it. The crushed quartzite grades into shattered rock and this into quartzite that for the most part is merely irregularly fissured. On the hanging-wall side of the gouge the quartzite is much fissured, and in many places shattered, for a width of 300 feet or more. (See Pl. XXI, p. 160.)

There has undoubtedly been considerable movement along the Bunker Hill fissure, but its amount and direction are unknown. The quartzite in the foot wall is of the same kind as that in the hanging wall. The fissure itself is nearly everywhere in soft ground subject to movement in various directions in consequence of local stresses, so that regular striations such as might give some clew to the direction of the original fault movement are not available for study. Striations and slickensides were observed at various places, but these showed such diversity of direction as to prove unreliable criteria for the determination of the principal direction of faulting.

In the Canyon Creek and Mullan group of mines the indications of considerable displacement along the planes of the lodes are less evident than at Wardner. The Tiger-Poorman lode is a mineralized fissure zone in which individual fissures pinch out and are succeeded by others. Such a structure is suggestive of slight or moderate rather than profound dislocation. There is no single persistent seam of gouge as in the Bunker Hill and Sullivan and Last Chance mines. Some movement of the opposite walls of the zone past each other undoubtedly took place, however, and was apparently effected under heavy stress, as is shown by the development of rough cleavage or schistosity in the quartzites alongside of and parallel to the lode. The complexity of the Tiger-Poorman zone of fissuring appears to exhibit at least two orders of magnitude. The lode worked in the mine is made up of many nonpersistent fissures and taken as a whole is probably merely one or more links in a chain of fissuring extending from Burke northwestward through the Custer mine. There is no apparent difference in the rock of the hanging and foot walls in the Tiger-Poorman mine, and the direction of such relative displacement of the opposing walls as has taken place is not known. As in the Wardner mines, there has been some movement along the lode since the deposition of the ore. This movement has been nearly horizontal, with a slight dip to the east, as shown by striations on the 1,800-foot level.

The Hecla lode, which lies about 1,000 feet southwest of the Tiger-Poorman, is coincident with a fissure zone generally similar to that of the Tiger-Poorman. Some of the individual fissures, however, appear to have been wider than in most of the Canyon Creek mines, attaining widths up to 2 feet. There is no definite evidence of important faulting along the lode. The hanging and foot wall rocks are alike and nothing was found on which to base any conclusion as to the amount and direction of possible faulting. After the formation of the ore a basic dike was injected along the general plane of the lode, without, however, any notable displacement of the ore. There has been some movement along the lode since the intrusion of the dike. The amount and direction of this later movement are not known.

The Standard-Mammoth lode is possibly in the same general zone of fissuring as the Hecla, although the two lodes, as will presently be shown, are certainly not continuous. As in the Hecla and Tiger-Poorman lodes, practically no facts were found that throw any light on the faulting along the fissure zone prior to ore deposition. The general character of the fissuring, however, and the absence of any single dominant fissure indicate only moderate displacement. Here, as in the Hecla and Tiger-Poorman mines, the quartzites are locally schistose close to the ore. They appear in some places to have taken on this structure in part subsequently to ore deposition. The ore is generally accompanied by a seam of gouge, indicating some movement along the lode since the ore was deposited. This seam is in some places within the ore; in others it occurs to one side or the other, forming a local wall between ore and quartzite.

The lodes near Mullan were originally zones along which the quartzitic beds were squeezed and sheared with the development of a local schistose structure accompanied by a multitude of small fractures. The total movement was not sufficient to produce long single fissures or to form persistent sheets of gouge or breccia and the lodes are not important as faults.

## CLOSING OR ENDING OF FISSURES.

In general the length of a fissure is roughly proportional to the amount of displacement produced by the dislocation. Great faults are either individually long or are linked or associated with other faults which in turn take up part or all of the throw. The Osburn fault, for example, with a maximum observed throw of 6,000 feet, has been traced for nearly 30 miles and is probably even longer. The Dobson Pass fault, with a still greater throw, has been followed for nearly 10 miles, terminating to the south at the Osburn fault. In comparison with these great persistent fissures the lodes of the Cœur d'Alene district are relatively short, a fact that accords well with the conclusion reached along other lines of investigation, that the lode fissures are not important as faults.

The longest single ore-bearing fissure, so far as known, is the Bunker Hill fissure, which is also the one that shows most evidence of being a plane of considerable movement. It is somewhat exceptional, moreover, as is more fully shown on page 126, in the fact that the ore can scarcely be said to occur in the fissure proper, but is found in large, irregular bodies in the hanging wall. The Bunker Hill fissure has a known length of about 7,000 feet and is accompanied by ore bodies for at least 5,000 feet. East of the Sullivan ore bodies the fissure has been explored in the east Reed drift (see Pl. XIX, p. 156) for more than 1,000 feet. It appears gradually to lose its distinctive character in this direction, but owing to the accumulation of foul air in this part of the Bunker Hill and Sullivan mine it was not possible in 1904 to determine what becomes of this part of the fissure. To the northwest, as shown in Pl. XIX, the Bunker Hill fissure has not been traced underground beyond its intersection with the Jersey fissure. By some it is supposed to continue through the Sierra Nevada mine; by others to pass through the Senator Stewart, Silver King, and Crown Point claims. It is probable that neither of these hypotheses is correct, but that the Bunker Hill fissure, if it crosses Deadwood Gulch at all, meets the Osburn fault between Deadwood and Government[a] gulches, somewhere near the Senator Stewart mine, and there ends. The surface exposures in this vicinity are very meager and the question of the northwestward extension of the Bunker Hill fissure will not be definitely settled until some underground work is done under Deadwood Gulch. The fissure has been explored to a depth of about 1,700 feet vertically below the highest point of outcrop, or about 2,400 feet measured down the dip. It is as distinct on the lowest level, the Kellogg tunnel, as near the surface.

The Skookum or Jersey fissure, which, as explained on pages 160 and 161, has had an important influence on the deposition of the ore bodies of the Last Chance and Bunker Hill and Sullivan mines (see Pl. XIX) apparently ends at the Bunker Hill fissure. It is probably a minor zone of fissuring which was formed at the same time as the Bunker Hill and Sullivan fissure and may not extend more than a few hundred feet from the latter. Exploration has not been carried far enough, however, to determine whether it continues to any considerable distance beyond the southwest limit of the ore bodies.

Structurally the Tiger-Poorman lode may be considered as extending from a point about 1,200 feet east of the Tiger shaft to a point beneath the old Union workings, a total distance of over 4,000 feet. The Hidden Treasure tunnel (Pl. XXV, p. 172) has shown that a fissure, apparently continuous with the lode developed in the Tiger shaft, extends at least thus far to the northwest, and it is possible that the same fissure, or one in the same zone, continues into the Custer mine. The productive part of the lode, however, is about 2,000 feet in length, and constitutes the southeastern half of the fissure zone as now known. In the present state of the mine it is not possible to ascertain the exact conditions under which the ore comes to an end northwest of the Tiger shaft. There is a strong suggestion, however, from the plan of the underground workings (Pl. XXV) that the ore stops at a nearly north-south cross fissure with easterly dip. As the fractures corresponding to the Tiger-Poorman lode continue past the position of this supposed fissure, the latter is probably not a fault of later age than the ore but is a feature that may antedate ore deposition and may have acted as a barrier to ore-bearing solutions which might otherwise have worked out toward the Union mine.

Toward the southeast the Tiger-Poorman lode becomes irregular, splitting up into a system of linked and imbricated fissures, as is more fully described on pages 173 to 174. On levels 8 and 12 the ore ends sharply at a well-marked fault which crosses the line of the lode nearly at right angles. This fissure, which Mr. Calkins has mapped (Pl. II, in pocket) as the O'Neil Gulch fault, strikes north and south and dips east at an angle of 75°. It is marked by a zone of sheared and crushed quartzite, in large part several feet wide and in most places containing one or more seams of gouge. The ore stops abruptly at the first gouge seam and is slickensided, showing

[a] The gulch west of Deadwood; not included within the map forming Pl. II.

that part of the dislocation at least is later than the ore. It is quite possible, however, and even probable that the fissure originated prior to ore deposition and that the lode has no continuation east of it. On the 1,200-foot level Prichard slate appears east of the fault, and as this formation is stratigraphically below the Burke quartzite the dislocation has the local character of a steep reverse fault.

No trace of the Tiger-Poorman lode has been found east of the O'Neil Gulch fault; in fact, the 1,200-foot level is the only one that has crossed it.

None of the levels below the 1,200-foot has reached the O'Neil Gulch fault. Levels 13, 14, and 15 are regarded as stoped out, the ore becoming too low in grade to work at a distance of about 1,200 feet east of the Tiger shaft. Level 16, at the time of visit, had attained a point under O'Neil Gulch. On this and on levels 17 and 18 the lode is apparently more regular than on the upper levels, and although the east faces of all these levels were in lean material at the time of visit they showed no evidence of any break in the general continuity of the fissure zone.

The Hecla lode has been followed for a distance of over 3,000 feet and the length of the pay shoot is approximately 1,200 feet. The underground workings have not yet reached either end of the fissure zone.

The Standard-Mammoth lode has a known length of approximately 2,000 feet. On the east it terminates abruptly against a fissure which may be called the Standard fault. The effect of this fault in cutting off the ore is shown in fig. 9 (p. 124). On the west the ore body is not so sharply limited. Above the No. 6 level (see Pl. XXVII, p. 176) the ore becomes narrow and the lode fissures less distinct as one goes west. The west face of this level shows only a narrow fissure about an inch wide carrying a little siderite and quartz and accompanied by some shearing of the quartzite. Apparently there was never much displacement along the Standard-Mammoth lode and such movement as took place diminished gradually toward the west. The fissures representing the lode in the extreme western part of the mine are so feeble that they die out and are lost in the presence of minor cross fractures. Below the No. 6 level the Mammoth mine is undeveloped and it is possible that future work will throw considerable light on the behavior of the lode toward the west.

The Standard fault strikes northwest and dips northeast at angles ranging from 65° to 70°. As may be seen from Pl. XXVII and fig. 9, it meets the lode obliquely so that the ore extends considerably farther east on each successively lower level. The fault has not been recognized at the surface, where the facts that it is entirely within the Burke formation and that the steep slopes above the mine are covered with soil and vegetation render it invisible. No. 4 and No. 5 tunnels of the old workings (Pl. XXVII) both follow the Standard fault for several hundred feet before they reach the vein. Exposures of it are also to be had at the eastern ends of the 450, 650, and 850 foot levels as well as in the Banner crosscut from the Campbell tunnel and on the No. 6 level of the Mammoth workings. In the crosscut the fault is marked by about 5 inches of dark clay gouge on the foot wall, with from 10 to 12 feet of crushed and sheared quartzite in the hanging wall. The material is soft as a whole, but tightly seals the fissure and appears to be comparatively impervious to water. The quartzite is generally sheared and slaty in the vicinity of the fault.

The relation of the Standard fault to the ore is such as to suggest at once that the lode is cut off by a younger fissure. This was the view taken by J. R. Finlay[a] and is the one generally accepted in the district. The Banner crosscut (Pl. XXVII) was driven on the hypothesis that the fault is normal and that the portion of the lode east of the fault would accordingly be offset to the south. Unfortunately the development east of the fault was not carried far enough either to prove or to discredit this interpretation. If the fault is really later than the ore, the problem of the recovery of the displaced portion of the pay shoot on the northeast side of the dislocation is well worthy of attention. As the ore is generally wider near the fissure than anywhere else in the mine, there ought to be, somewhere just northeast of the fault, an ore body of such size that there would be no danger of crosscutting through it unaware. It is true that there is little clue to the amount and direction of the throw of the fault, owing to the homo-

[a] The mining industry of the Cœur d'Alenes, Idaho: Trans. Am. Inst. Min. Eng., vol. 33, 1903, p. 247.

geneous character of the rocks traversed; but the fact that the fault has not been recognized as a factor in the general geological structure of the district would indicate that it has not a very great displacement, although this might easily amount to several hundred feet and still escape detection in geological mapping at this particular place. If an approximately vertical throw be postulated, the offsetting of a lode so nearly vertical as the Standard-Mammoth should not be very great. On the supposition of a horizontal throw, or heave, the facts that the Standard-Mammoth lode is in line with the Hecla lode east of the fault and that it is obviously in the same general zone of fissures which contains both the Hecla and the Tiger-Poorman lodes are rather opposed to the idea of great displacement. In short, if the fissures represent a fault subsequent to ore deposition the conditions are favorable for the recovery of the eastern part of the lode. There is good reason, however, for questioning the opinion that the dislocation is in the main later than the ore.

When an ore body is found to be cut off by a barren fissure filled with the soft product of trituration known as gouge the conclusion that the ore has been faulted is usually and, in many instances, correctly drawn. If the direction and extent of the fault movement can be ascertained, the continuation of the ore can generally be found without difficulty. If these data are not available, right and left crosscuts are perhaps run on the far side of the fault and continued until the ore is found or the search is abandoned.

The literature of ore deposits, however, affords several examples of barren gouge-filled fissures which are as old or older than accompanying fissures filled with ore. The famous silver veins of Andreasberg, in the Harz Mountains, are confined to a wedge-shaped block of ground between two strong faults, called by the miners *ruscheln*, or rotten veins.[a]

Lindgren,[b] in describing the De Lamar mine, near Silver City, Idaho, states that—

> It has long been the opinion of those connected with the mine that the veins are faulted by the clayey rhyolite or the "iron dike," and that consequently their continuation might be found beyond this crushed mass, but this belief is probably not justified. * * * When the fissures which were to receive the mineral-bearing solutions were broken open, the force which readily shattered the brittle rocks spent itself in vain against the tough clayey "iron dike," and thus the veins are apparently cut off by the latter. * * * This clayey wall acted as a barrier, damming the solutions and causing the more abundant deposition of mineral matter below it; at the contact, indeed, the most intense action took place and the richest ore bodies were found.

The Cashen fault in the Gold Coin mine, in the Cripple Creek district, is probably also a fissure that is older than the ore that ends against it.[c]

As a rule, fault fissures once initiated, particularly if they are filled with gouge rather than with quartz or other solid vein material, continue to be planes of movement for long periods. Accordingly if an ore-filled fissure ends against a gouge-filled fissure of the same or greater age, the latter may and usually does show some displacement which is clearly later than the ore. In such a case the determination of the relative age of the ore and the cross fissure may offer some difficulty, and it is advisable before discussing the phenomena in the Cœur d'Alene district to consider the criteria that may be useful in determining whether a given fissure dislocates the ore or is anterior to ore deposition.

If the ore-bearing fissure is older than the fault its primary structural features should be independent of the latter. If the ore is banded, for example, the bands should be cut off sharply at the postdepositional fault. Usually there will be fragments of ore in the crushed material between the walls of the disturbing fissure. On the other hand, if the fault is older than the ore-bearing fissure the latter is likely to exhibit some characteristic change in the vicinity of the cross fracture. It may split up into smaller fissures, it may be wider here than elsewhere,

[a] Beck, R., Erzlagerstätten, Berlin, 1901, pp. 288–290; also English translation by W. H. Weed, New York and London, 1905. See also Hoppe, O., Über die mechanischen Vorgänge im Innern und an der Oberfläche der Erde mit Berücksichtigung der sogenannten "faulen Ruscheln" am Harz: Zeitschr. f. prakt. Geologie, vol. 15, 1907, pp. 139–143.

[b] The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 159.

[c] Lindgren, W., and Ransome, F. L., Geology and gold deposits of the Cripple Creek district, Colorado: Prof. Paper U. S. Geol. Survey No. 54, 1906, p. 489.

or it may possibly, in some rare instances, be narrower. If the ore is banded the bands will turn across the lode and join at its end or they will merge into a massive structure. Although the ore at the cross fissure may be slickensided by later movement, it will not as a rule be sufficiently broken up to be dragged into the fault.

In practice these criteria are not always available. It is conceivable that in a lode formed mainly by replacement of the wall rock the ore may exhibit a banding which will be truncated at the fault even when the latter is anterior. The fault may be later than the ore and yet contain no visible crushed or dragged ore, or it may have originally antedated the ore and yet in consequence of vigorous later movement exhibit every appearance of being a postdepositional fault, although of course there is no continuation of the lode beyond it.

The fact that one fissure may contain ore and another hold only a soft mass of claylike gouge is not in itself proof that the barren fissure is younger. A gouge-filled fissure appears to be distinctly unfavorable to ore deposition, probably in part because the gouge chokes the fissure and prevents the access of mineral-bearing solutions and in part because the movement along such a fissure is so nearly continuous as to give no chance for the deliberate and undisturbed chemical action which seems requisite for the formation of large, clean bodies of ore.

Examination of the Standard-Mammoth lode in the vicinity of the Standard fault failed to yield entirely decisive evidence as to the relative age of ore and fault. That some movement has taken place along the Banner fissure since the ore was deposited is plain. On the other hand, the lode presents certain features which suggest that the fault was anterior to mineralization. The lode is generally widest and richest near the fault and on the lower levels divides nto two branches just before reaching the fissure. Both of these facts are what might be expected on the supposition that the Standard fault is older than the lode. It is unlikely, on the other hand, that a fault having a decided inclination from the vertical would cut the lode so as to coincide on practically all levels with the widest and richest part of the ore shoot. The banding of the Standard-Mammoth lode, parallel to its walls, is not very distinct. So much of this structure, however, as was visible at the time of visit seemed not to be sharply cut off at the Standard fault, but to become less distinct or to show some tendency to curve and meet across the end of the lode. So far as known, no drag ore has yet been found in the Standard fault. These facts, and the failure to find beyond the fault the continuation of an ore body having such width immediately to the west of it, strongly suggest, if they do not prove, that the Standard fault is older than the Standard-Mammoth lode.

The Helena-Frisco mine contains three veins which, as shown in the plan, fig. 20 (p. 180), are apparently parts of a once continuous lode that have been displaced by cross faults. The difficulties in the way of this view, however, are the diverse characters of the three veins and the lack of evidence for the existence of cross faults of sufficient magnitude to effect so great a horizontal displacement of the supposedly older fissures. The apparent cross faults are fissures which are probably formed before or contemporaneously with the opening of the lode fissures. This hypothesis could not be verified in 1904, owing to the inaccessible condition of many of the levels. The mine has since been reopened and it is possible that future observations may throw some light on the relations of the Gem, Frisco, and Black Bear veins.

In the Morning mine the principal lode had been productively developed in 1904 for a length of nearly 2,000 feet, without revealing any end to the fissure zone either to the northwest or to the southeast. The fissures, however, are inconspicuous and carry no ore at the southeast end of the workings.

In the Gold Hunter mine the lodes are parts of a shear zone at least 70 feet wide. They are narrow plates of sheared and fractured rock lying parallel to the general schistosity and cleavage of the country rock and are individually not very persistent. The productive part of the entire zone is about 1,000 feet in length, but no single stopes are over 250 feet long. The fissures can rarely be followed far beyond the end of an ore body, as within a short distance they become lost in the general fissility of the slaty country rock.

Up to the present time the depths attained on the productive lodes are in nearly all cases less than the known horizontal extent of the lodes. The Bunker Hill fissure, for example, has a length of at least 7,000 feet and is productive along a distance of nearly a mile. The extreme vertical range of development on this fissure did not, in 1904, exceed 1,700 feet. The Standard-Mammoth lode, with a developed length of 1,800 feet and a known vertical range of 2,600 feet, is apparently exceptional, but future developments will undoubtedly considerably extend the total known lode length. The Tiger-Poorman has a developed lode at least 4,000 feet in length, 2,000 feet being productive, with a known vertical range of about 2,000 feet. The Morning lode is fully 3,500 feet in length and has been vertically explored for 2,300 feet.

There was no evidence in 1904 to indicate that any of the important fissure zones were becoming narrower with increasing depth.

## SHAPES AND DIMENSIONS OF PAY SHOOTS.

Various causes have combined to render the study of the forms of pay shoots in this district particularly unsatisfactory. Even with accurate and complete stope maps, it is generally not easy to gain a clear conception of the shape of an ore body, for the outlines of stopes can not be assumed to correspond to any natural, definite, or consistent division between ore and country rock. Blocks of comparatively good ore may be allowed to stand in certain stopes, while in others everything is removed except country rock. When the maps are incomplete, as is the case in the Cœur d'Alene district with regard to many of older workings, it is impossible to obtain any satisfactory idea of the general outline of an ore body in the plane of the lode.

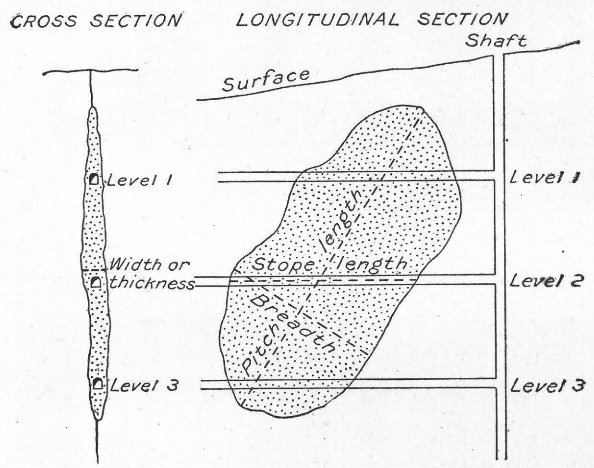



FIG. 6.—Diagram illustrating use of terms in descriptions of pay shoots.

Throughout the following pages the shape and attitude of pay shoots or ore bodies will be described in terms whose usage is illustrated in the accompanying diagram (fig. 6).

In the comparatively regular lodelike deposits, such as those of the Canyon Creek and Mullan groups, the width of pay shoots ranges from 3 to 40 feet. The maximum width is attained in parts of the Hercules and Morning lodes, the average stoping width of the Morning lode, however, being estimated at about 9 feet. In the Tiger-Poorman and Standard-Mammoth lodes the width of the stopes does not as a rule exceed 15 feet. The Hecla lode is on the whole narrower, although much of it is from 5 to 6 feet in width.

The stope map of the Morning lode, which is shown complete to the summer of 1904 (fig. 7), indicates the existence of a main pay shoot of nearly vertical pitch, which is small near the surface but increases to a stope length of about 1,200 feet in the No. 5 tunnel, approximately 1,200 feet below the apex of the shoot. Since the mine was studied the No. 6 tunnel has cut the lode 1,000 feet below the No. 5 tunnel, and intermediate levels have been run, showing a continuance of the ore body downward. According to Mr. W. Clayton Miller,[a] general manager for the Federal Mining and Smelting Company, the ore shoot seems to pitch to the west on these lower levels, but it is clear that sufficient work to establish this definitely has not yet been done.

In the Tiger-Poorman mine the stopes above the 1,100-foot level have not been accurately mapped. The pay shoot on the whole seems to have been very regular on the upper levels, with a stope length of about 1,200 feet and a pitch to the southeast of about 20°. On the 1,600-foot level the stope length of the main pay shoot, so far as one can judge from abandoned stopes, was about 1,000 feet (fig. 8). As described on page 173, some of the lower levels show a succes-

[a] Personal letter of August 16, 1906.

sion of overlapping or imbricated pay shoots east of the shaft. Stopes on these shoots are in most places not distinguishable in the stope map from those on the main or No. 1 shoot. It is questionable in any event whether they should not all be considered as parts of one general pay shoot.

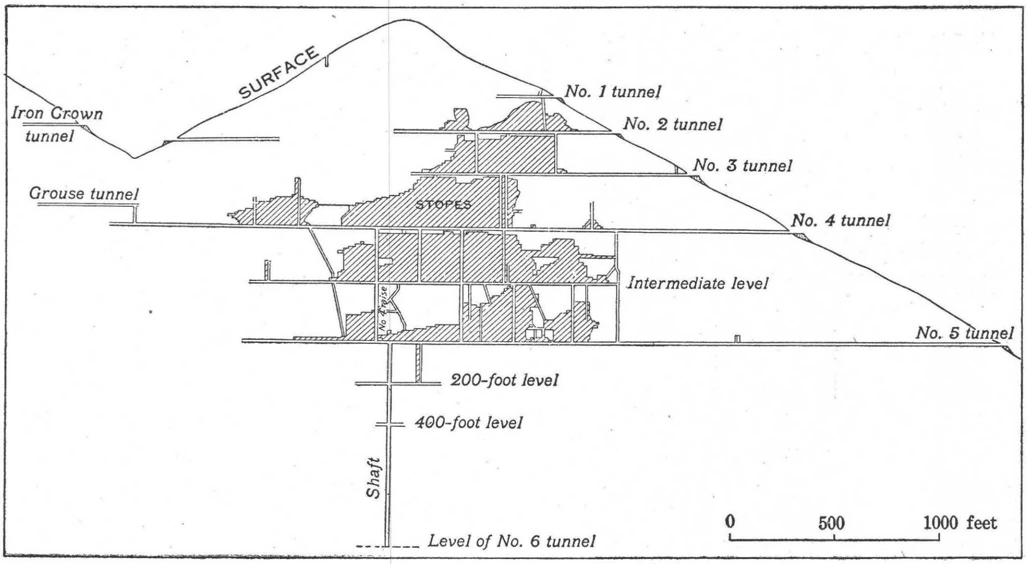



FIG. 7.—Longitudinal section of Morning lode, showing ground stoped up to end of 1904. The ore is now known to extend down to the No. 6 tunnel.

The stopes in the Standard-Mammoth mine as they were in the summer of 1904 are shown in fig. 9. Here the Standard mine has been worked to much greater depth than the Mammoth, so that the shape of the pay shoot in the latter is still to be determined. The old stopes, more-

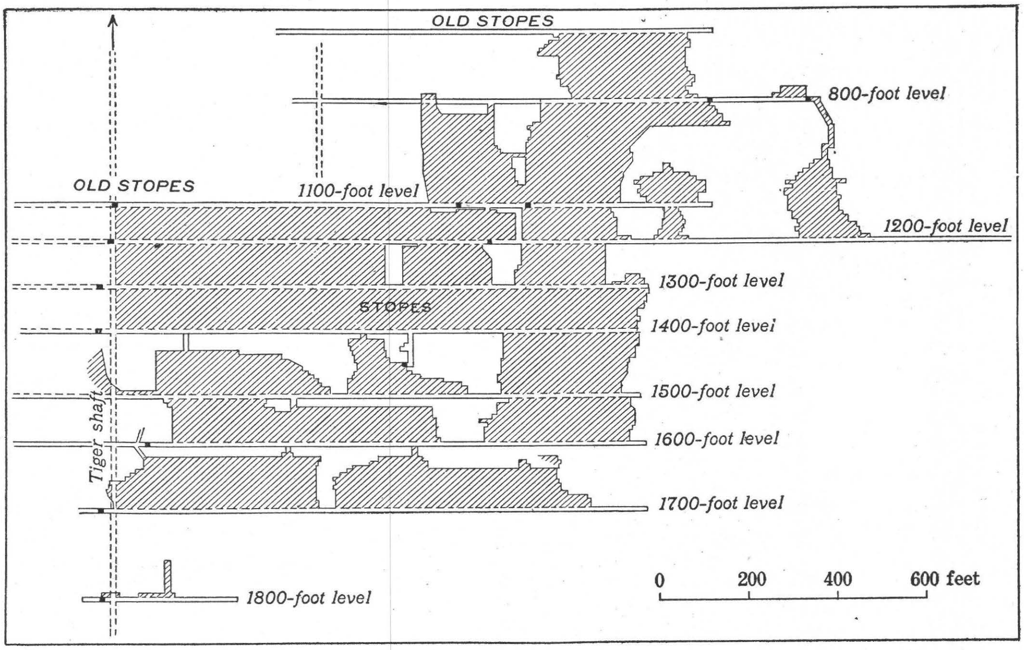



FIG. 8.—Longitudinal section through the Tiger-Poorman mine, showing modern stopes. Old stopes above the 600-foot level not shown.

over, above the No. 5 level are not mapped. On the whole the workings suggest a pay shoot about 1,800 feet in stope length which gives promise of being longer and more continuous below the No. 6 level than above it. On the southeast the ore is sharply bounded by the Standard fault. On the northwest its limits remain in great part to be discovered. The pitch of the whole pay shoot will probably be found to conform to the line of intersection of the Standard fault with the lode. In other words, the shoot will probably pitch to the southeast at an angle of about 20°.

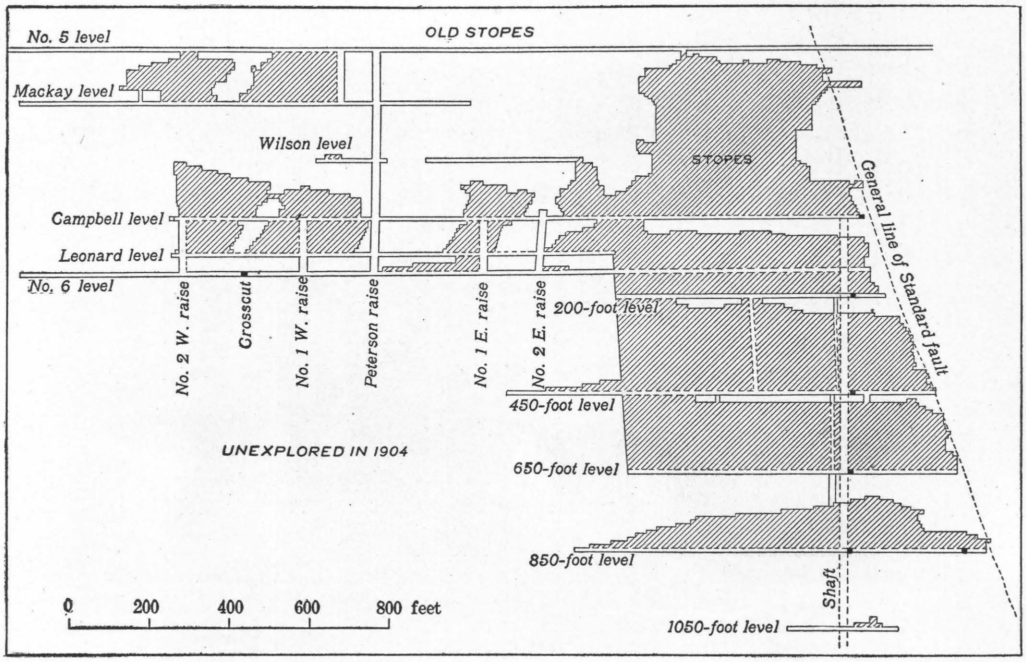



FIG. 9.—Longitudinal section through the Standard-Mammoth mine, showing modern stopes.

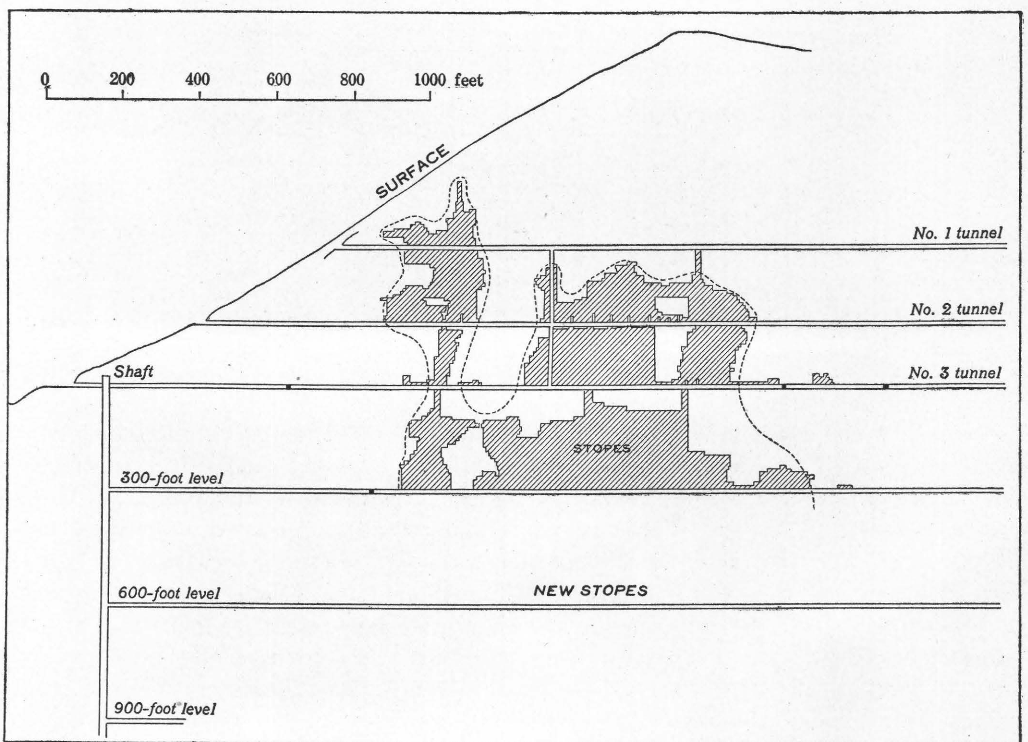



FIG. 10.—Longitudinal section through the Hecla mine, showing stopes in 1904.

The Hecla mine shows a pay shoot (fig. 10) about 1,000 feet in stope length, with a tendency to split up and become smaller near the surface. The pitch is apparently vertical.

The Helena-Frisco mine (fig. 11) shows five pay shoots, two on the Black Bear vein, one on the Frisco vein, and two on the Gem vein. The largest shoot, the Frisco, ranges from 450 to 900 feet in stope legnth and is known to have a pitch length of over 2,100 feet. The pitch is practically vertical. An unusual feature in this ore body is a reversal of dip below the 1,800-foot level. According to the map of the workings, the lode dips to the south at an angle of about 82° from the surface to the 1,800-foot level. Below this level the lode apparently dips to the north and is less regular. As the mine was full of water up to the adit in 1904, this change in dip could not be investigated.

The principal shoot on the Black Bear vein ranges from 100 to 400 feet in stope length and is known to have a pitch length of over 1,100 feet. The pitch is slightly to the southeast. The main ore body in the Gem lode has a stope length of 800 feet in the upper tunnels, but apparently contracts below tunnel No. 3 to about 250 feet and becomes still shorter at greater depth. The ascertained pitch length is 1,000 feet. A short distance southeast of this ore body is a

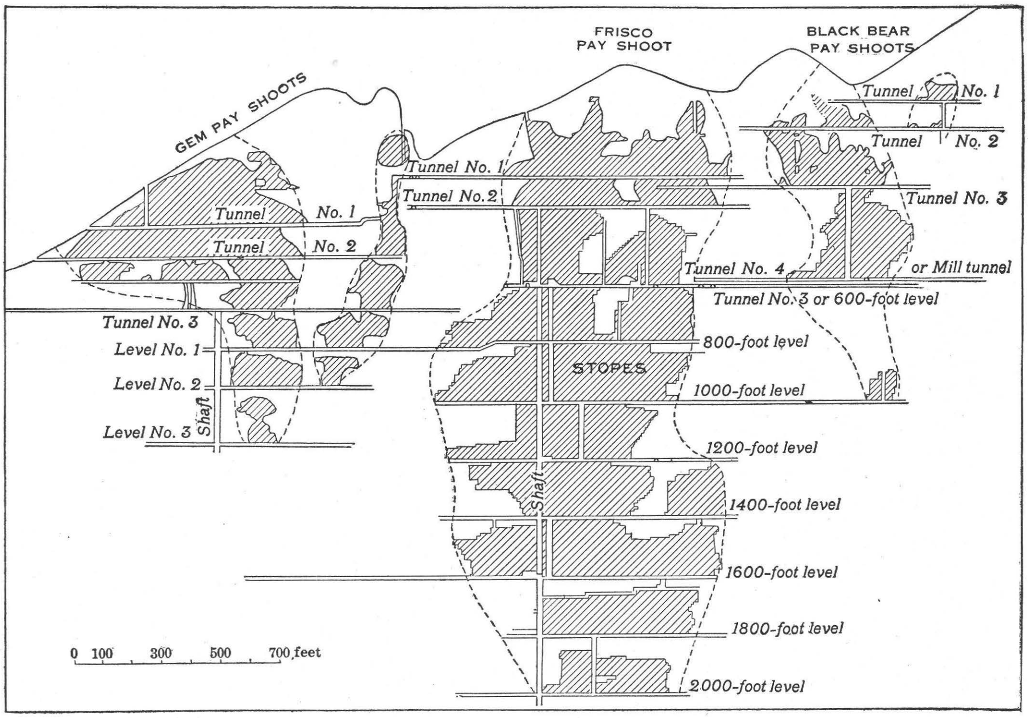



FIG. 11.—Longitudinal section through the Helena-Frisco mine, showing stopes.

pipelike pay shoot with a general northwest pitch of about 15° and a maximum stope length of 250 feet. The known pitch length of this body is 900 feet.

The stopes of the Helena-Frisco mine have been mapped from the surface down, and as the mine is also one of the deepest in the district these maps are particularly useful in giving some clue to the probable shape of the pay shoots in the deposits of lode form. If these shoots may be regarded as at all typical of the district it is important to observe that they are of nearly vertical pitch and that their pitch lengths greatly exceed their stope lengths. In other words, their axes of greatest elongation are practically vertical. The Frisco shoot, with an average stope or breadth of about 600 feet, has a known pitch length of at least 2,100 feet. Some of the smaller shoots of the Helena-Frisco mine have apparently been worked almost to the bottom of the ore and even in the main Frisco shoot the stope maps, taken in connection with the history of the mine, suggest some diminution in the size and value of the ore body on the deeper levels. When the mine is unwatered and work resumed, the latter conclusion may prove to be wrong; but, to grant for the present its probability, the information furnished by this mine is rather encouraging than otherwise as regards the future of the other lode mines in the district. The pursuit of this line of investigation, however, will be reserved for a later section. (See p. 130.)

To the lodelike deposits just described the ore bodies found near Wardner in connection with the Bunker Hill fissure offer a striking contrast. Those are tabular bodies of fairly uniform width, though of irregular outline, lying in the planes of nearly vertical fissure zones; these are more or less rotund masses irregularly distributed through the shattered quartzite in the hanging wall of the fissure but nowhere in the foot wall. (See fig. 12.) Some of the ore bodies are in contact with the foot wall of the Bunker Hill fissure; others are separated from it by a hundred feet or more of barren shattered quartzite. No considerable bodies of ore, however, extend farther than about 300 feet from the foot wall, measured perpendicularly to the latter, or about 500 feet as measured on one of the mine levels in a direction at right angles to the strike of the main fissure, which, it may be remembered, dips 38° SW. Within this huge slab of shattered rock, 300 feet thick, which intervenes between the Bunker Hill or "foot wall" fissure and the comparatively unbroken quartzite, forming what may be termed the general hanging wall of the ore-bearing ground although the change from broken to unbroken quartzite is not sharp, lie the ore bodies. These as a rule have no definite boundaries, although here and there

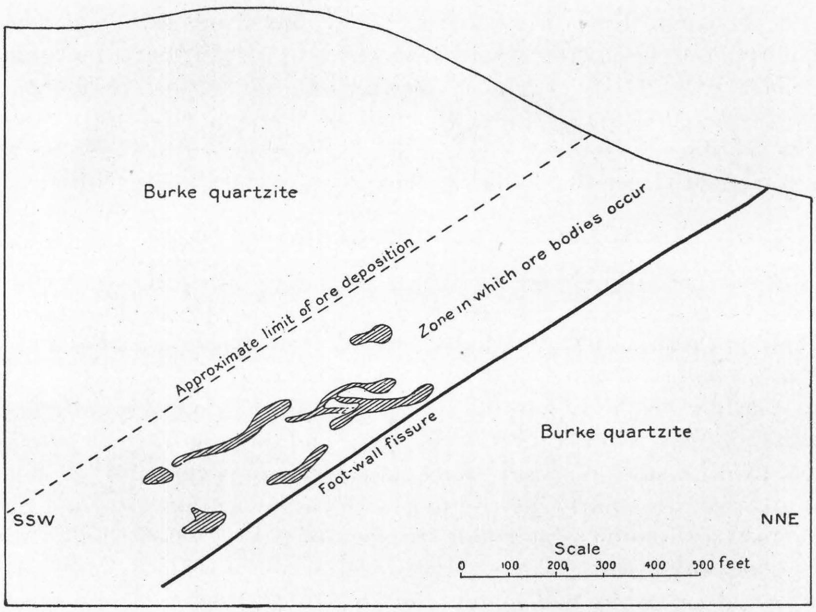



FIG. 12.—Actual section through one of the most important productive parts of the Bunker Hill and Sullivan ore zone, showing ore bodies stoped.

the ore is limited on one side by the gouge of the Bunker Hill fissure or on one or more sides by some of the minor hanging-wall fissures.

It is difficult to convey a satisfactory idea of the dimensions of ore bodies so lacking in regularity or to represent their forms without recourse to models. Individual pay shoots may be 500 feet in stope length, 100 feet or more in width, and 300 or 400 feet in depth. These single masses of ore usually have their greatest dimension more nearly horizontal than vertical and are thus in marked contrast to such lode pay shoots as occur in the Helena-Frisco mine.

The whole zone of fissured rock, 300 feet in width, may, however, be broadly regarded as a single great lode and it then appears that the partly overlapping and partly connected ore bodies are not distributed evenly throughout the zone but are grouped into at least four fairly distinct shoots, as may be seen in Pl. XIX (p. 156). For details regarding these compound shoots the reader is referred to the description of the Wardner mines on pages 154 to 163. It is enough to say here that three of them, the Sullivan, Bunker Hill, and Blacksmith shoots, so far as shown by present developments, pitch to the northwest at angles near 45°. The fourth, or Last Chance shoot, which lies in the angle between the Bunker Hill and Jersey fissures, pitches in general to the southeast. In these compound shoots, made up of many single ore bodies, the pitch length, measured along a line in the plane of the Bunker Hill fissure at an angle of 45° with the line of maximum dip, exceeds the stope length, and the deposit as a whole becomes to some extent comparable with the lodes of Canyon Creek.

Among the smaller pay shoots of the district, those of the Sierra Nevada and Granite mines deserve some notice here on account of their exceptional characters.

The pay shoot of the Sierra Nevada, now worked out, was a fairly regular curved sheet, in few places over 6 feet in thickness, forming part of a metasomatic fissure vein of unusually low dip. Much of the ore was nearly horizontal, but the dip increased toward the southeast to about 20° and beyond the limits of the pay shoot, in this direction, the lode becomes still steeper, as may be seen in Pl. XIX. A somewhat similar blanket-like pay shoot occurred in the Crown Point mine (see p. 161), but this ore body was more irregular in thickness and its formation was accompanied by more replacement of the quartzite country rock than in the Sierra Nevada vein.

The ore bodies of the Granite mine are not only exceedingly irregular in shape but differ from all other known lead-silver deposits in the district in that they are not connected with any dominant or persistent zone of fissuring. They are irregularly distributed through a tongue of metamorphosed sediments which projects into an intrusive monzonitic mass. So far as the pay shoots exhibit any regularity at all, they are suggestive of lenses standing on edge. These are connected at many points by small, tortuous pipes of ore. Some idea of these curious pay shoots may be had from fig. 22 (p. 185). All are small and the entire block of ground in which they occur is not larger than some of the stopes in the Bunker Hill and Sullivan mine.

### DETAILED STRUCTURE OF PAY SHOOTS.

Two general kinds of internal structure may be distinguished in the Cœur d'Alene lead-silver deposits, one associated with the large, irregular masses of the Wardner mines and the other with the Canyon Creek and Mullan lodes. Neither of these structural varieties, however, is restricted to the ore bodies of which it is most characteristic.

The typical Wardner ore body may be briefly described as an obscurely bounded mass of shattered quartzite, largely altered to siderite and inclosing numerous irregular bunches of galena of all sizes up to masses of nearly pure lead sulphide several feet in diameter. These bodies of galena are very irregularly distributed, with ragged peripheries, and grade outwardly into siderite traversed by innumerable small stringers of galena which coalesce here and there into bunches of considerable size. The stringers are notable for their small size, few of them being over a fraction of an inch in width and many not much thicker than a sheet of paper, and for their intricate and close reticulation. So closely crowded are they near the best ore that a slight increase in thickness would result in the formation of a bunch of nearly pure galena, and it is evident that they represent an intermediate stage in the complete replacement of quartzite by galena. In this way the fragements of the shattered quartzite have been attacked by the ore-bearing solutions not only on their outer surfaces but along multitudes of originally microscopic cracks within each fragment. (See Pl. XIII, *A*, p. 110.) The result has been that such fragments have been in many localities replaced completely and simultaneously by galena and scarcely any of the ore shows the concentric shelly structure observable where the ore-bearing solutions have been limited, by lack of permeability in the rock affected, to a merely peripheral attack on the fragments.

Not all of the Wardner ore bodies, however, are wholly of this type. Much of the ore along the Jersey fissure zone in the Last Chance and Bunker Hill and Sullivan mines occurs in large, solid stringers which have clearly filled open fissures. The material of such stringers is usually more quartzose than the ore formed chiefly by replacement. In some places the fissures have been filled from wall to wall with massive galena, as a rule inclosing rounded and distorted crystals of quartz several inches in length. The minerals in these stringers, so far as observed, have crystallized without any recognizable banding parallel to the walls.

The large ore bodies of the Wardner mines are at many points cut by fissures which are younger than the mass of the ore. Along such fissures the galena is in places rendered schistose and in other places has been crushed and recrystallized in compact aggregates—the so-called teel galena which in these mines is usually richer in silver than the galena that has not undergone this secondary crystallization.

The second type of internal structure is developed in the pay shoots of the Canyon Creek mines and consists of a rather irregular and in many places indistinct banding of the ore parallel to the walls of the lode. This banding is due to the fact that part of the ore occupies fissures and part consists of more or less thoroughly replaced slabs of quartzite between the original openings. Although the banding is described as parallel to the walls, it should be understood that in all the large Cœur d'Alene mines the ore is only exceptionally and locally separated from the country rock by a definite plane. As a rule the ore grades into country rock through a zone that may be several inches in width or may even be measurable in feet.

In some places, as in the Standard-Mammoth mine, the stringers themselves show depositional banding, siderite having crystallized near the walls and quartz along the middle. Where the ore is best, the intervening slabs of sheared quartzite are solidly replaced by galena and the banding of the lode may be quite obliterated.

The ratio between ore that has filled fissures and ore that has replaced quartzite varies in the different lodes. In the Tiger-Poorman and Hecla the proportion of ore that has crystallized in definite stringers is rather greater than in the other lodes of Canyon Creek or in the Mullan lodes. In the Morning lode replacement has played a very prominent part, and much of the ore is not unlike that of the Wardner mines in structure.

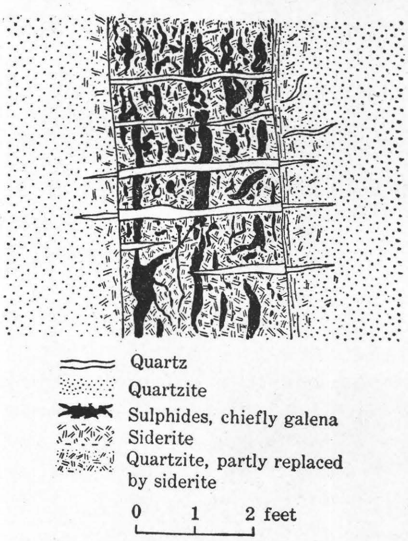


FIG. 13.—Generalized sketch of part of Standard-Mammoth lode, showing structure.

A very noticeable feature in the Standard-Mammoth lode is a crossbarring of the lode by nearly horizontal stringers of white quartz which are clearly younger than the mass of the ore, although some of them contain a little galena and tetrahedrite. Many of these stringers are confined to the ore. Others extend into the wall rock, but nearly all of these become much smaller in the quartzite and pinch out within a few feet of the lode, as shown in fig. 13. Small, nearly horizontal stringers of barren quartz are abundant in the quartzite wall rocks of most of the Canyon Creek lodes. Like the stringers which cross the ore in the Standard-Mammoth mine, they almost invariably pinch out within a few feet of the lode. Both sets of horizontal gashes appear to have resulted from local tension along the lode, produced by some comparatively recent slight tangential movement of the walls and ore. Evidence for such movement is found not only in the slight gouge present in many places on one or both walls of the ore but in the abundant development of local schistosity in the quartzite which is directly in contact with the ore. It is evident that in the Standard-Mammoth lode there can have been no considerable slipping between walls and ore since the formation of those cross stringers which extend from the ore into the country rock.

Banding of the character just described is not wholly absent from the Wardner deposits and was noted particularly in 1904 in the Edna stope, then just opened on the third level of the Last Chance mine. Here some of the galena, with quartz and sphalerite, filled clean-cut fissures, while other parts of the breast showed banding due to replacement of sheeted quartzite.

In lodes such as those of Canyon Creek and Mullan, which are coincident with zones of shearing and parallel fissuring that may reach considerable widths, it is to be expected that in many places an individual streak of ore will be found to pinch out and to be succeeded by another streak in an adjacent fissure or shear plane. Such structure of subordinate pay shoots en échelon is found in the Gold Hunter and Tiger-Poorman mines.

The Hecla lode is intimately associated with a dark basic dike, as described on page 176. The dike is younger than the ore, which is not noticeably metamorphosed. It follows the pay shoot on the whole, here and there cutting obliquely across the ore from side to side.

## RELATIONS OF ORE BODIES TO SURFACE AND DEPTH.

### CONDITIONS OF OUTCROP.

As a rule, all but the steepest slopes in the district are covered with soil which supports a thick growth of vegetation. The material of the lodes, moreover, is neither so superior in hardness and durability to the surrounding rock as to form bold outcrops nor so easily eroded as to produce marked trenches or saddles in the topography. Consequently the outcrops of the largest lodes and ore bodies are usually very inconspicuous and probably would not attract the attention of even a keen observer traversing the country in the ordinary way. The Mullan road was carried through what has since become the most productive part of the district, but over twenty years elapsed after its completion before the prospectors and settlers who passed over this old highway began to realize that the dark, forested slopes above them concealed mineral deposits worthy of their attention. Their wealth surmised, the hills were soon prospected and most of the important lodes were quickly discovered; but it is significant of the inconspicuous character of the deposits at the surface that the ore body of the Hercules, one of the largest and richest in the region, was unknown until the year 1900.

The Bunker Hill ore shoot, which was one of the first discovered, showed galena at the surface, mixed with cerusite, limonite, and a little copper carbonate. The direction of the Bunker Hill fissure, however, was not recognized by the locators of this and adjacent claims, who laid out their side lines parallel to the outcrop of some prominent beds of quartzite and thus provided for future litigation. Both the Bunker Hill and the Sullivan mines were originally worked by open cuts. Later development showed that while the Sullivan and Bunker Hill pay shoots came to the surface, others along the Bunker Hill or "foot wall" fissure did not. In the Tyler workings, for example, the great compound shoot which has supplied most of the ore from the Last Chance mine can hardly be said to outcrop at all. (See Pl. XIX, p. 156.) Of course many of the individual ore bodies making up such great compound shoots as the Bunker Hill or Sullivan are wholly subterranean and have no visible connection with the surface beyond their common association with the main "foot wall" fissure. The exceptional Sierra Nevada deposit of the Wardner group outcrops along the hillside at the head of Deadwood Gulch and was stoped from the surface in.

In the Mullan group all the principal lodes showed ore at or very close to the surface, although in no case can the outcrops be called conspicuous. At the Gold Hunter mine the ore, containing partly oxidized galena and tetrahedrite, comes to the surface and was being taken out by lessees in 1904 immediately beneath a thin cover of soil and grass. It would be impossible, however, to trace the lode for any distance by mere inspection of the original surface.

At the Morning mine a shallow cut just below the road to the No. 4 tunnel exposes the top of the Morning ore shoot, containing some galena, but the lode can hardly be said to have any visible outcrop. The course of the You Like vein is equally obscure on the surface, although the old upper tunnels show that oxidized ore extended up to the superficial covering of soil.

Among the Canyon Creek group the Hercules lode shows no outcrop (see Pl. XXVI, *A*, p. 174) although the oxidized ore probably comes to the surface. The Hecla pay shoot, as shown in fig. 10 (p. 124), does not extend to the surface and is for the most part below the No. 1 tunnel. The ore body was discovered in the No. 3 tunnel, after it had been driven about 800 feet. The outcrop of the fissure is traceable with difficulty over the surface, and the same may be said of the Tiger-Poorman lode. In the Standard-Mammoth lode oxidized ore occurs practically at the surface, but the lode shows no outcrop that can be followed without the aid of test pits.

## GENERAL RELATION OF WORKINGS TO TOPOGRAPHY.

Taken all together the workings of the Cœur d'Alene lead-silver mines show a total vertical range of a little over 4,000 feet. The vertical position of each mine with reference to the others and to the general relief of the region is shown in Pl. XIV, which exhibits graphically the comparatively early stage of development of the Morning, Hercules, Last Chance, and Bunker Hill and Sullivan mines and the depth attained in the Tiger-Poorman and Helena-Frisco mines.

## CHANGES IN ORE WITH INCREASING DEPTH.

In spite of the vertical range of exploration attained by most of the large mines, the ore shoots, below the zone of oxidation, show very little change in mineralogical character or in tenor. In the Bunker Hill and Sullivan, Last Chance, Morning, Hercules, and Hecla mines as well as in others of less depth, no change in character of the sulphide ore could be detected between the upper and lower levels, in 1904. Since then the Bunker Hill and Sullivan has sunk 400 feet below the Kellogg tunnel and the manager, Mr. Stanly A. Easton, reports no change in the ore—certainly no decrease in tenor. In the Morning mine, also, the ore has been cut in the No. 6 tunnel, 800 feet below the deepest part of the ore body visible in 1904. As regards this ore, Mr. W. Clayton Miller, general manager, wrote on August 16, 1906; "There seems to be very little difference in the ore below, except that we have had some better silver values, but I am inclined to think that this is a local condition."[a]

In some of the Canyon Creek mines which have gone to greater actual depths than those just mentioned, as may be seen from Pl. XIV, there are some indications of a change in the ore which is apparently a function of depth and not of any variation in the country rock.

In the Tiger-Poorman the best ore was found above the 600-foot level. Pyrite, pyrrhotite, and sphalerite are increasingly abundant on the lower levels and form a larger proportion of the ore on the 1,800-foot level than anywhere else in the mine.

In the Standard-Mammoth tetrahedrite and chalcopyrite seem rather more abundant above the 650-foot level than below it and pyrrhotite is more common on the 1,050-foot level than above. Sphalerite and pyrite also appear to be increasing with depth.

The deep levels of the Helena-Frisco mine were under water in 1904 and the only clue to the character of the ore is that afforded by the records of the mine. These suggest that the ore became leaner with depth—that is, galena became less abundant while the proportion of pyrite and zinc blende increased.

At the Gold Hunter mine ore containing abundant tetrahedrite and galena and said to carry up to 140 ounces of silver to the ton and 53 per cent of lead occurs near the surface. No such ore is known in the lower workings, where the average is 6 per cent of lead and 7 to 8 ounces of silver, with 60 ounces as a maximum.[b]

Although the data obtainable in regard to changes in the ores with depth are not altogether conclusive, they indicate that the larger Cœur d'Alene ore bodies, wonderfully persistent as they are, are likely to become poorer at depths ranging from 1,000 to 2,000 feet below the grade of the South Fork of the Cœur d'Alene. The bottoms of most of the mines, as may be seen in Pl. XIV, are still far above the levels at which the ore may be expected to show any falling off in value, and even in those where there is perhaps some evidence of decreasing tenor it by no means follows that profitable mining is nearly at an end.

Although it can not be asserted that the process of ore enrichment by the deposition of secondary sulphides is entirely absent from the zone in which partial oxidation prevails, yet it is probable that any such enrichment is exceedingly local. There is no evidence that the changes in the character of the ores, which have just been discussed, are due to this process. Such changes are probably entirely independent of oxidation or of solutions that may have descended from the oxidizing zone.

[a] Personal letter.

[b] Recent reports, however, indicate that ore similar to that of the upper levels has been found in a new tunnel 500 feet below the No. 5 tunnel.

U. S. GEOLOGICAL SURVEY

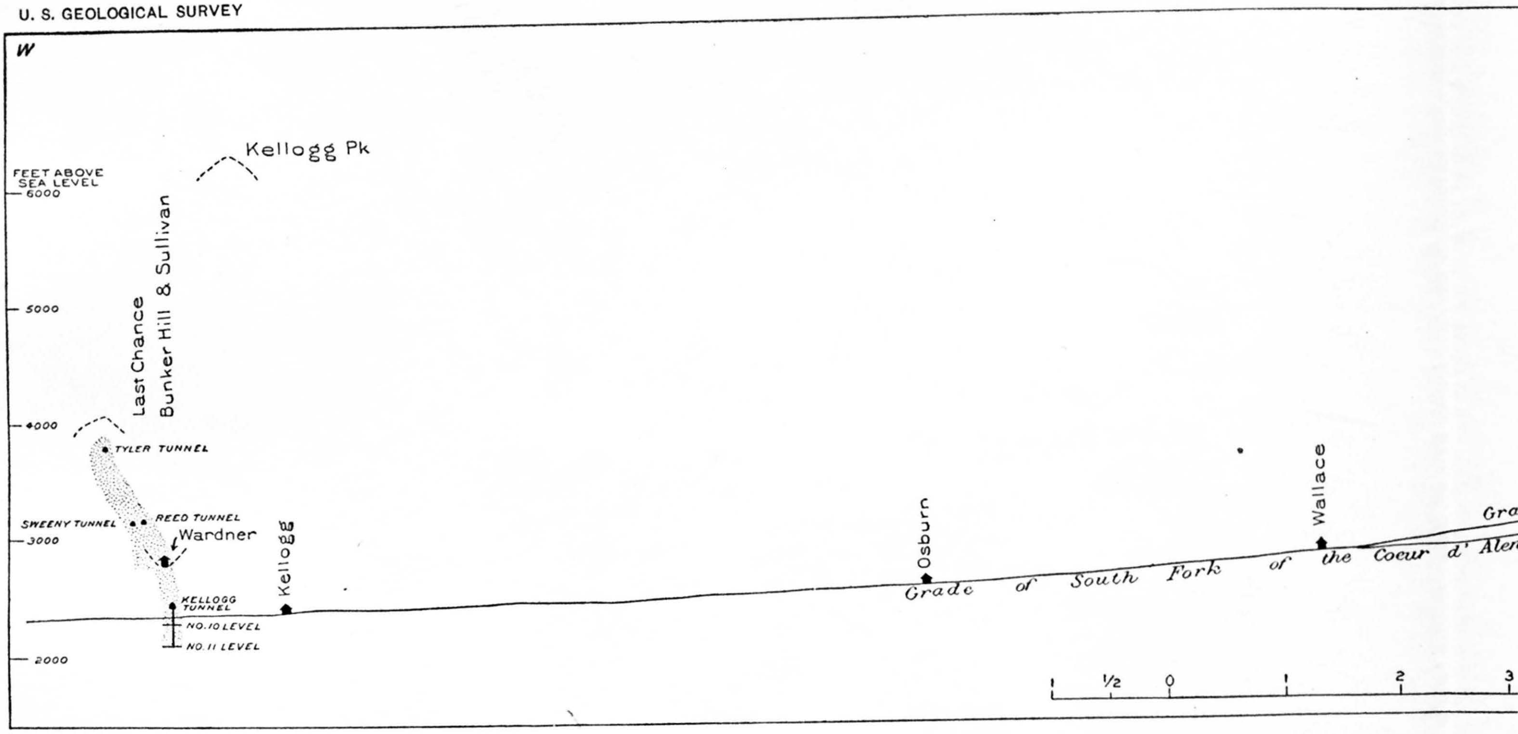



DIAGRAM SHOWING RELATION OF PRINCIPAL LEAD-SILVER DEP

The dotted areas are intended merely to represent the general vertical range of the ore bodies as develo

## GROUND WATER.

In this region of heavy precipitation, abundant springs, many faults, and strong relief, the original underground water surface, before its disturbance by mining operations, was probably exceedingly irregular and nowhere very far from the topographic surface. All the mines are wet, although the quantity of water encountered varies greatly with the situation and character of the workings.

In September, 1904, the Tiger-Poorman was pumping about 550 gallons a minute from its 1,950-foot shaft and the near-by Hecla about 150 gallons a minute from a 900-foot shaft. In the spring months the pumps of the Tiger-Poorman frequently have to raise 1,000 gallons a minute. The Standard-Mammoth in 1904 was pumping about 130 gallons a minute from the 1,050-foot level. Mines like the Hercules, Morning, Bunker Hill and Sullivan, and Last Chance, with workings above the grades of the principal streams of the district, show only moderate quantities of water, which is easily drained through the adits. The Morning is well called a wet mine, not so much on account of the great quantity of water encountered as because of a pervasive dripping through all the workings. Compared with the water found at Cripple Creek, where the precipitation is much less, the water held in the Cœur d'Alene rocks, even in such situations as that of the Tiger-Poorman mine, with a deep shaft under the bed of a stream, is rather surprisingly small.

That the rocks of the district are not equally permeable and that large pockets of water may in consequence occur high above the main streamways is shown in the Snowstorm mine, near Mullan. The No. 3 tunnel, about 1,200 feet above the valley of the South Fork, ran through Wallace slates for nearly 1,700 feet. It then passed through a fault gouge into Revett quartzite, which was found to be saturated with water, the flow from the tunnel, as estimated in 1904, being between 700 and 1,000 gallons a minute. This water, which was clear and cold and formed no deposit, poured from every crack and crevice in the quartzite at the time of visit.

In the Tiger-Poorman a large part of the water comes from the upper levels and the seasonal fluctuations show that most if not all of the water pumped is merely rain or snow water that has found its way down through the rocks and more directly through the old stopes.

In the Wardner mines the water issues at all levels, except some of those directly drained from below, from fissures in the quartzites and from diamond-drill holes. It is in general heavily charged with carbonate of iron and on exposure to the air throws down the iron as a slushy deposit of ferric hydrate which covers the walls and accumulates on the floors of unused drifts. Some diamond-drill holes furnish an abundant flow, whereas others are nearly dry, showing that the rocks are by no means evenly saturated or equally porous.

A sample of water, collected from a drill hole in the face of the Madden crosscut on the west Reed level, was examined by Dr. Eugene C. Sullivan in the chemical laboratory of this Survey. The water, which, like all others in the mine, was depositing abundant ferric hydrate in the crosscut, was perfectly clear as it issued from the drill hole and the bottles were sealed at once. A slight sediment had been deposited when the sample reached the laboratory. A qualitative examination showed the total solids in solution to be about 70 parts per million, consisting chiefly of bicarbonates and sulphates of calcium and magnesium with some silicic acid, iron (mostly in sediment), manganese, sodium, and potassium. Nearly half of the solids in solution consisted of calcium bicarbonate. A special test for lead showed a minute trace—possibly one part in ten million. There is evidently nothing about this water suggestive of deep-seated origin. It is probably meteoric and has gathered its solid constituents in its passage through the rocks of the district by the decomposition of such minerals as the feldspars, siderite, calcite, and dolomite.

In conclusion, it may be regarded as extremely doubtful whether any of the mines have yet tapped underground water which did not originally fall upon the Cœur d'Alene Mountains as rain or snow. Nothing suggesting the present occurrence of magmatic or juvenile waters has yet been brought to light.

## OXIDATION.

The important chemical and mineralogical changes involved in the oxidation of the lead-silver ores are the conversion of the argentiferous galena to cerusite and native silver and of the siderite gangue to limonite. In some deposits a subordinate quantity of natural litharge or massicot is associated with the cerusite. Pyromorphite occurs in the oxidized ore of the Hercules and in a few prospects. It seems to have been one of the latest minerals to form in the upper part of the zone of oxidation, for it occurs in crusts and implanted crystals upon other products of oxidation such as limonite. It is readily produced by the action of downward-percolating water, which when containing carbonic acid is capable of decomposing apatite in the soil and rock traversed. Plattnerite, the dioxide of lead, was found in the oxidized part of the You Like lode. Anglesite, the sulphate of lead, has not been recognized in the district. That the galena should for the most part change to cerusite is easily understood in light of the fact that the accompanying conversion of the siderite gangue to limonite sets free abundant carbonic anhydride, which probably goes into solution, partly free and partly combined with calcium, magnesium, and, where oxygen is deficient, with some iron, in the form of bicarbonates. The direct oxidation of galena should give the lead sulphate, anglesite, and in districts where the oxidizing waters are deficient in carbonates or rich in sulphuric acid or sulphates, as for example the San Juan district in Colorado,[a] anglesite is a common alteration product of galena. Penrose[b] states that the oxidation of the lead sulphide to sulphate is a necessary step in the formation of cerusite from galena, and Emmons[c] found at Leadville that chemical tests showed the occurrence of a thin crust of anglesite between the galena and cerusite. In the Cœur d'Alene district, however, no anglesite has been detected, the sulphide and carbonate being directly in contact. The galena, however, does not pass into compact cerusite but is replaced by loose bunches of crystals, many of which are of large size. As a rule, masses of galena in process of oxidation show irregularly etched or corroded cavities upon the walls of which are implanted crystals of cerusite. It is clear that in the formation of these large free-growing crystals considerable molecular or ionic migration must have taken place, and it is quite possible that under such circumstances and in the presence of abundant carbonates in solution the anglesite may have formed and been immediately changed into cerusite, the process being such that no visible quantity of anglesite could accumulate. Even where the ore contains bunches of almost completely oxidized pyrite, as in the Last Chance mine, and where sulphates or sulphuric acid were presumably more than usually abundant, the galena, directly in contact with the porous limonite resulting from the oxidation of the pyrite, has altered to cerusite with no visible anglesite.

It is not quite clear why, under these conditions, some smithsonite or calamine has not formed from the sphalerite. The latter mineral, however, was not abundant in the ores subjected to oxidation and it is by no means certain that special chemical investigation would not reveal a corresponding small quantity of zinc in the oxidized ores.

The alteration of galena to cerusite involves an increase of volume of about 28 per cent, while the change from siderite to limonite produces a contraction in volume of 37 per cent, and from pyrite to limonite a decrease of 23 per cent. As the oxidized ore is invariably much more porous than the sulphide ore it is evident that the contraction due to the change from siderite and some pyrite to limonite, with the probable loss of some material carried away in solution, overbalances the expansion in volume due to the transformation of the lead sulphide into lead carbonate.

Although some of the ores, such as those of the Last Chance, Gold Hunter (upper tunnels), and Standard-Mammoth, contain some tetrahedrite or chalcopyrite, none of the oxidized lead-silver ores visible in 1904 showed any notable quantities of oxysalts of copper. Malachite in the form of stains or thin crusts is locally present and azurite is rare. Native copper or oxides of copper have not been noticed in these deposits by any observer, so far as known.

[a] Ransome, F. L., A report on the economic geology of the Silverton quadrangle, Colorado: Bull. U. S. Geol. Survey No. 182, 1901 (reprinted 1903), p. 87.

[b] Superficial alteration of ore deposits: Jour. Geol. vol. 2, 1894. p. 297.

[c] Mon. U. S. Geol. Survey, vol. 12, 1886, p. 546.

The lower limit of oxidation is very irregular. Cerusite has been noted in vugs and along fractures in ore and country rock at depths of several hundred feet, while galena may occur in the croppings. Thus in the Last Chance mine lead carbonate and limonite are found in parts of the Sweeny tunnel level that are at least 700 feet below the outcrop, whereas in the Bunker Hill mine galena was discovered at the surface. The Morning, Gold Hunter, and Standard-Mammoth lodes may also be named as among those in which the ore at the surface is only partly oxidized. The oxidation in the Morning lode is said to have extended to a maximum depth of about 200 feet. The Sullivan ore shoot of the Bunker Hill and Sullivan mine and the You Like lode of the Morning mine appear to have contained thoroughly oxidized ore near the surface, and much of the upper part of the Last Chance shoot is comparatively free from sulphides. The only large body of carbonate ore visible in 1904 was that of the Hercules. Even in this body, however, the oxidation is incomplete except near the surface. In the No. 2 tunnel and in the stopes for some distance above it the coarsely crystalline, porous cerusite ore containing limonite incloses large residual bunches of nearly pure galena. Here, as in most of the other ore bodies of the district, oxidation has attacked first those parts of the ore containing pyrite and sphalerite, the solid masses of galena proving more resistant to atmospheric agencies. The result of this selective action was also very well shown in 1904 in the No. 1 stope near the Sweeny level of the Last Chance mine.

# CHAPTER IV.—GENESIS OF THE LEAD-SILVER DEPOSITS AND PRACTICAL CONCLUSIONS.

## GENESIS.

### ORIGIN OF THE FISSURES.

The lead-silver ores of the Cœur d'Alene district have been deposited along relatively subordinate fractures in a region cut by numerous faults of large displacement. The structurally important fault fissures which have been described by Mr. Calkins on pages 62 to 64 do not, so far as known, contain any ore bodies of commercial importance. They are for the most part filled with crushed rock, much of it ground to the consistency of clay, and appear to have continued as planes of movement up to the present time. The relation of the ore-bearing fissures to the great faults is nowhere clearly shown. It is probable, however, that they were formed substantially at the same time as the major dislocations and are the effect of stresses set up within the faulted blocks in consequence of their displacement. If this supposition is correct it follows that the major faulting played an important part in the initiation of conditions favorable to ore deposition, and the origin of the faulting is thus a starting point in attacking the problem of ore genesis.

The reconnaissance work of Mr. Calkins to the north and east of the area here considered has shown that faulting of the kind described in this report is not confined to the Cœur d'Alene district but prevails over a region so wide as to rule out any attempt to explain it as a merely local phenomenon. The conditions that brought it about affected practically all of northern Idaho and a considerable part of Montana. It is not surprising, therefore, that the detailed study of a single district, supplemented by some rapid reconnaissance, has failed to throw much light on a problem so obscure as the cause of regional faulting. It seems most reasonable to regard it as in some way related to the intrusion of the great granitic (quartz monzonite) batholith of central Idaho, of which the main exposed mass, as Lindgren[a] has shown, probably extends northward to a point within 40 or 50 miles of the Cœur d'Alene district. In fact, there is reason to suppose that the comparatively small monzonitic and syenitic intrusions exposed within the district, and other masses known to occur south of the area covered by this report, are all parts of the same batholith and that the exposures of granitic rocks would be much more extensive were the Cœur d'Alene region more deeply eroded. That the intrusion of so vast a body of magma under and through the pre-Cambrian sediments and its subsequent solidification could have taken place without producing, over wide areas, some notable structural modifications in the sedimentary rocks is scarcely credible, even under the supposition, favored by Mr. Calkins, that the magma made room for itself by deep-seated assimilation of the invaded rocks. Some of the fissures, notably the Dobson Pass fault, cut the monzonite, but this does not invalidate the foregoing suggestion as to their origin. Deep-seated portions of the batholith were probably still mobile long after the portions now exposed in the district had solidified. Moreover, the total displacement effected by the faults is probably the algebraic sum of many slow movements, some of which may not yet have entirely ceased.

The ore-bearing fissures themselves show no faulting of sufficient magnitude to appear in a geological map, and even underground the recognizable slipping of one wall past the other (tangential displacement) is usually measurable in inches rather than feet. It must be said, however, that the conditions for detecting and measuring moderate displacement in the Cœur d'Alene rocks are by no means favorable owing to the absence of thin distinctive beds such as might be utilized as registers of the movement.

[a] A geological reconnaissance across the Bitterroot Range, etc.: Prof. Paper U. S. Geol. Survey No. 27, 1904, Pl. I.

The Bunker Hill fissure, which, as described on pages 159 to 161, does not itself carry ore, shows evidence of being a plane of considerable movement. (See Pl. XXI, p. 160.) It may be regarded as intermediate in some ways between the typical barren faults of great throw and the typical metasomatic veins occupying fissures of slight throw

That the productive fissures are not mere gaping cracks due to tension, but were formed under conditions of pressure tending to squeeze the walls together, is shown not only by the presence of gouge, as in the Bunker Hill fissure, but by the close association between fissuring and schistosity displayed in the Morning and Gold Hunter mines and to a less degree in the Canyon Creek lodes. As described on page 167, it is impossible in some parts of the Mullan deposits to draw any sharp distinction between fissuring, with the production of molar spaces of discission, and shearing, with the production of schistosity. The general parallelism of most of the fissures also points to the dominance of compressive stresses in their formation. Whether these compressive stresses resulted from a direct thrust by the magma as it made its way through the sediments, or whether they record a settling down or collapse of the uparched beds in consequence of a decrease in bulk of the cooling and solidifying batholith, is undetermined.

Neither of the foregoing hypotheses requires that all of the fissures should be formed at the same time. The presence of lamphrophyric dikes, such as those of the Hecla and Helena-Frisco mines, which cut the ores, shows in fact that some fissuring took place after some of the ore had been deposited.

### SOURCE OF THE ORES.

The great vertical range of the Cœur d'Alene ore bodies—fully 4,000 feet (see Pl. XIV, p. 130), the shape of such pay shoots as those of the Helena-Frisco mine, shown in fig. 11 (p. 125), the lack of any dependence of deposition on the details of the present topography, and the absence of irregular or crevice deposits not directly connected with persistent fissures all point to the derivation of the ores from considerable depth and to their precipitation from ascending solutions. The mineralogical character of the ores, moreover, indicates that the depositing solutions were hot and under high pressure.

Fissures, while a necessary factor in the formation of most epigenetic ore deposits, are rarely sufficient as channels for ordinary, cold underground water to effect the intense local concentration, within what are called mineral districts, of metals generally distributed through the rocks in quantities too small to be detected by the ordinary methods of chemical analysis. It is well recognized that ore deposits are exceptional and very local occurrences and consequently that the conditions determining their deposition are as a rule unusually complex. Two factors, fissuring and the presence of igneous rock, have been shown to be almost universally present and in most districts are undoubtedly genetic conditions of prime importance. Other determinative factors are to be found in the character of the country rock and in its attitude or structure, especially with reference to intrusive masses. In view of these general and preliminary considerations, the possible relation between the Cœur d'Alene ores and the intrusive masses of monzonite shown in Pl. II (in pocket) invites attention.

At first glance the monzonitic masses appear inadequate to account in any way for the ore deposits, some of which, as at Wardner, are 8 miles from the nearest small exposure of the intrusive rock. Moreover, the distribution of the ore deposits shows no obvious symmetry with reference to the monzonite areas. The monzonite exposures, however, are merely the upper parts of masses which become larger with depth, so that some of them doubtless coalesce a few hundred feet below the surface, and the erosion of a few thousand feet of rock from the whole region would probably expose a large area of monzonite in the central part of the district, with smaller outlying areas where at present no intrusive rock is known. Mr. Calkins has shown on page 51 that the contact metamorphism on Dudley Creek indicates close proximity to the upper surface of a batholith. In short, while there is no present means of proof, the assumption that the sedimentary rocks of the district rest in part upon a great mass of intrusive granitic rock, which is probably a portion of the main Idaho batholith, appears to be well founded. It is known that just south of the Cœur d'Alene district the pre-Cambrian sediments are intruded and metamorphosed by granitic rocks and these occurrences help to link the Cœur d'Alene intrusions with the vast granitic mass in the central part of the State, from which the sedimentary cover has been stripped away. In its southern part the batholith exhibits a relation to the sediments similar to that assumed in the Cœur d'Alene Mountains, Lindgren's geological map of west-central Idaho[a] showing isolated granitic intrusions projecting through the sedimentary rocks in the vicinity of Hailey.

A study of the mineralogical character of the Cœur d'Alene ores brings out certain variations that are definitely related to the monzonitic intrusions. The ores of the Granite and Sixteen-to-One mines, both of which are situated in the contact zone encircling the largest of the monzonitic masses, contain abundant sphalerite, as well as galena, accompanied by pyrite, pyrrhotite, magnetite, and chalcopyrite. The sulphides and magnetite are in some places intergrown with red garnet and are intimately associated with biotite and diopside. In the Granite mine particularly the ore occurs in exceedingly irregular bunches in the metamorphic sediments and is unquestionably a product of some phase of contact metamorphism. Siderite is apparently wholly absent, the principal gangue mineral being quartz, although very little true vein quartz is present. Irregular bunches of ore in many places show a gradation from galena in the center to sphalerite and pyrite on the periphery, and these minerals in turn grade into an outer envelope of garnet and other metamorphic minerals.

In the Helena-Frisco ore bodies, also situated near the contact, siderite is absent or extremely rare, and the ore, except in the Black Bear vein, where it is chiefly galena and quartz, is sphaleritic and contains pyrrhotite, pyrite, and chalcopyrite. In the Gem vein, which is nearest the monzonite, the sulphides are in places intergrown with garnet and green biotite. If, as seems probable, the specimen collected by Mr. Lindgren and referred to on page 99 came from this mine, tourmaline is also to be added to the list of vein minerals.

The ore of the Hercules mine shows less intense contact action than those just described, but siderite is not abundant, some of the ore is sphaleritic, and the sulphides are in some places intercrystallized with green biotite. At one place an asbestiform mineral, probably anthophyllite, was found intergrown with galena. The Hercules is some distance from the contact with the monzonite as exposed on the surface, but a decomposed dikelike offshoot occurs in the mine.

In the Tiger-Poorman and Standard-Mammoth mines siderite is only moderately abundant and the ores contain notable quantities of sphalerite and pyrrhotite. These sulphides are apparently increasing a little in quantity with increasing depth, particularly the pyrrhotite in the Tiger-Poorman. Pyrite and chalcopyrite are comparatively abundant in both mines. The Hecla ore contains very little siderite, but otherwise shows no features to connect it especially with contact metamorphism. The mine, however, is not nearly so deep as the Tiger-Poorman and the ore now mined is probably farther from the monzonite than that of its deeper neighbor.

In the deposits near Mullan siderite is more plentiful than on Canyon Creek, especially in the Morning mine. Sphalerite and pyrite are moderately abundant and pyrrhotite less so than in the Tiger-Poorman and Standard-Mammoth lower levels. Barite and stibnite are apparently confined to the Mullan group of deposits.

In the Wardner mines siderite is more abundant than elsewhere in the district. Sphalerite is rare, pyrite subordinate, and pyrrhotite unknown. Garnet, biotite, pyroxene, and magnetite are entirely absent from these deposits.

The relative abundance of tetrahedrite is apparently not controlled by distance from the monzonite. It has not been noted, however, in those ores which, as in the Granite mine, are most clearly connected with contact metamorphism.

The foregoing facts indicate, not only that there is no definite mineralogical line to be drawn between such contact-metamorphic ore as that of the Granite mine and such siderite and galena ore as occurs in the Bunker Hill and Sullivan mine, but also that there is a fairly regular gradation from one type to the other. Garnet occurs only in the ores within the

[a] The gold and silver veins of Silver City, etc.: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, Pl. VIII.

recognizable contact zone of the monzonite. Siderite occurs only outside of the zone of metamorphic silicates. Sphalerite and pyrrhotite are most abundant in or near that zone and become less prominent constituents in deposits at a distance from the intrusive rock.

It is generally agreed at the present day that ores of the type found in the Granite mine have been deposited by solutions at high temperature and under heavy pressure. In fact, the conditions are believed to be such that it is doubtful to what extent the depositing agent was an aqueous solution and to what extent a mixture of gases above their critical temperatures.[a] That the hot solutions emanated from the underlying monzonitic magma appears to be beyond reasonable doubt. In the case of the Granite mine, for example, situated in a narrow tongue of sedimentary rocks almost surrounded by the monzonite, no other hypothesis to account for the source of the ores seems tenable. The further conclusion that all the lead-silver ores of the district emanated from the same source follows from the facts presented in regard to the mineralogical relations of the ores of the different groups of deposits. The solutions or gases as they issued from the monzonitic magma at high temperature and under heavy pressure first effected the metamorphism of the contact zone and deposited the ores rich in sphalerite and pyrrhotite associated with garnet and biotite. As the solutions penetrated farther through the fissured sediments they deposited the sideritic galena ores, comparatively free from sphalerite and pyrrhotite. As is the case with many other ore deposits associated with contact metamorphism, the most valuable ore does not lie in the zone of most intense metamorphic activity.

It is not supposed that the ores were derived from the comparatively small bodies of monzonite now exposed in the district. These themselves show some mineralization, as at the Sunset mine, where the monzonite is speckled with pyrite, and they may have entirely solidified before the principal mineralization was effected. The source of the ores is thought to lie in the underlying batholith from which the exposed masses are probably offshoots. As there is no thermal activity in the region at present, this magmatic reservoir has probably solidified as a monzonitic or granitic rock. A long period may have elapsed, however, between the cooling of the parts now visible and the crystallization of the whole mass. The occurrence of the Cœur d'Alene ores appears to furnish one more example of the remarkable dependence of mineralization on the intrusion of monzonitic rocks in the Cordilleran region.

At this place, however, it is necessary to recall the fact that some of the deposits in the Prichard formation, even though situated many miles from the nearest known exposure of monzonite, exhibit some mineralogical similarity to the ore of the Granite and other mines on Nine-mile Creek. This is particularly the case with the Pine Creek prospects, southeast of Wardner, in which both pyrrhotite and sphalerite are comparatively abundant. While these minerals alone are not conclusive evidence of contact-metamorphic action, yet their presence suggests, particularly as they occur in the stratigraphically lowest formation in the region, that the top of the batholith may not here be so deeply buried as to be wholly beyond the reach of mining operations.

The explanation here offered of the source of the Cœur d'Alene ores finds considerable support when the occurrence of these ores is compared with that of the Wood River silver-lead deposits described by Lindgren.[b] The Wood River mines are situated in Blaine County, near the town of Hailey, 300 miles south-southeast of the Cœur d'Alene district. The deposits occur in closely folded Carboniferous sediments consisting of limestone, quartzitic sandstone, and dark, banded calcareous shales. These are intruded by granite or quartz monzonite masses which are probably parts of the central Idaho batholith, the eastern border of the main granitic area lying about 10 miles west of Hailey. Like the Cœur d'Alene deposits, therefore, those of Wood River occur in sedimentary rocks bordering the central granitic mass and underlain, in all probability, by the intrusive rock.

The principal deposits of the Wood River region are in the shale and are metasomatic fissure veins, the bulk of the ore having formed by replacement of shale. The chief ore mineral

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[a] See Lindgren, W., The relation of ore deposition to physical conditions: Economic Geology, vol. 2, 1907, p. 112.

[b] The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 190-231.

is galena and the usual gangue is siderite or intermediate iron-calcium-magnesium carbonates. The ores carry more silver than those of the Cœur d'Alene distirct and some contain gold. A few veins cut the intrusive granite or quartz monzonite, and the exceptional Croesus vein, furnishing a gold ore consisting of quartz, calcite, siderite, pyrrhotite, pyrite, and chalcopyrite, is in diorite. Sphalerite and pyrite are possibly a little more abundant in the granitic rocks than in the shale. While the granitic rock has metamorphosed the sediments near the contact by the development of pyroxene, biotite, pyrrhotite, and other contact minerals, Mr. Lindgren does not trace any connection between such metamorphism and ore deposition.

The essential facts brought out by the comparison are the similarity in position of the two districts with reference to the Idaho batholith, the metasomatic character of both groups of deposits, the abundance in both districts of siderite, elsewhere a rather uncommon gangue mineral, and the general absence of conspicuous metasomatic alteration in the country rock outside of the ore bodies themselves.

The conditions in the Cœur d'Alene and Wood River districts indicate that disturbed sediments resting upon the gently sloping flanks of a batholith are favorably situated for ore deposition. As Lindgren[a] has pointed out, the great central granitic area of Idaho is conspicuously barren, most of the ore deposits being found in the older rocks about its margin. Many other deposits probably occurred in the sediments which once covered much of the quartz monzonite, but these have been swept away by erosion so deep as to have removed even their roots. It would seem, however, that the undeveloped country between the Cœur d'Alene district and the Clearwater River is one in which important ore deposits may yet be found.

The solutions as they issued from the intrusive rock must have contained the following constituents, the salts being undoubtedly more or less ionized: Water or steam, carbon dioxide, ferrous carbonate, sulphides of lead, zinc, iron, silver, and copper, sulphantimonites of copper, and much smaller quantities of sulphide of antimony, sulphate of barium, and some compound of boron. Carbonates of the alkalies and alkaline earths were probably also present and possibly hydrogen sulphide. Silica can not have been an abundant constituent.

Some of the sulphides were deposited at once in the contact zone simultaneously with the development of magnetite, pyroxene, garnet, biotite, and other contact minerals. Among those thus to be partly removed from the solutions were pyrite, pyrrhotite, and sphalerite. The greater part of the sulphide of lead and all of the ferrous carbonate traveled farther through the fissured sediments and under suitable conditions of temperature and pressure attacked and replaced the quartzitic rocks. So far as the microscope can show, the replacement of quartz by siderite is direct. As the ferrous carbonate was deposited from solutions poor in silica, the silica replaced was dissolved. Finally this dissolved silica appears to have been deposited in such neighboring open fissures as were available. In some localities, as in the Jersey fissure of the Wardner group of deposits, the quartz was deposited to some extent with galena as ore; but in many places it appears to have crystallized almost free from sulphides in stringers cutting the ore or traversing the country rock near the ore bodies. The process of deposition was probably slow and was certainly complex. In many places, as in the Wardner and Mullan mines, a large part of the galena certainly formed after the siderite, for it occupies fissures in the latter mineral. The direct attack on the quartzite is usually made by the siderite and not by the galena. There are numerous exceptions to this general rule however. Siderite, as pointed out on page 112 and illustrated in Pl. XIII, *D* (p. 110), may occur in two distinct generations. Siderite veinlets may cut quartz veinlets and vice versa.

The suggestion that the bulk of the quartz associated with the lead-silver deposits is a by-product from the attack of carbonate solutions on quartzite is not susceptible of proof and may possibly be questioned. It seems a reasonable explanation, however, in view of the fact that the ore-bearing solutions can not have been originally siliceous. Large quantities of quartzite were replaced by siderite and if the dissolved silica was not deposited in neighboring fissures it must have been carried to a distance, since silicification is not a feature of the wall rock near the Cœur d'Alene lead-silver deposits. The only widespread alteration in the country

[a] A geological reconnaissance across the Bitterroot Range, etc.: Prof Paper U. S. Geol. Survey No. 27, 1904, p. 85.

rock which can be connected with ore deposition is the rather extensive dissemination of siderite and minute crystals of tourmaline. Small crystals of pyrite may also be rather abundant in the quartzite within a few feet of the ore.

As indicated on page 107, the kind of country rock has undoubtedly had some influence in determining ore deposition. The fine-grained, somewhat argillaceous rocks, such as the Prichard slate, have not been as permeable or as readily replaced by ore as the quartzitic rocks of a little coarser grain, particularly those in which the quartz grains, instead of interlocking closely after the manner of pure typical quartzite, are partly embedded in a sericitic matrix. This sericite, which appears to have developed in the quartzites prior to the period of ore deposition, is usually first converted to siderite, the solid quartz grains being more resistant. The rocks of the Wallace formation, in spite of their partly calcareous nature, have not proved favorable to the formation of large metasomatic ore bodies.

The absence of ore from the great fault fissures would be readily enough accounted for were the veins simple fissure fillings. In the case of metasomatic deposits, however, it is not entirely clear why mineralization should be confined to the fissures that are not conspicuous faults. It is probable that the fault fissures, being filled with gouge, are relatively impervious to solutions and that frequent movements of the opposite walls tend to interfere with the slow movement of the depositing solutions and the undisturbed conditions most favorable to continued precipitation.

It is undoubtedly due to the impervious character of their fillings that many fault fissures have been important factors in the localization of ore bodies by acting as dams against which deposition could proceed. The pay shoots of the Standard-Mammoth and Hercules mines appear to have been partly determined in this manner. The most conspicuous example, however, of the influence of an impervious fault gouge is furnished by the Bunker Hill fissure. The contrast between the abundance of ore in the hanging wall and the absence of mineralization in the foot wall is one of the most remarkable features of the district. In what manner the ore-bearing solutions were originally conducted to the hanging-wall side of the fissure rather than to the foot wall is not entirely clear. It is probable, however, that at some considerable depth they were able to pass freely across the fissure where the gouge was not continuous. Once in the fissured hanging wall, they would rise along it and be prevented by the gouge from spreading into the foot wall.

In regard to the depth at which the ores now exposed near the surface were originally deposited the general geology of the region furnishes rather meager information. As Mr. Calkins has pointed out on page 75, the extensive development of cleavage or schistosity in the sediments and the character of much of the minor folding are indicative of deformation under heavy load. The monzonitic masses have the character of plutonic intrusives and their texture and the contact metamorphism associated with them shows that they probably cooled slowly under conditions that favored the long-continued emanation of vapors under heavy pressure and at high temperature.

Another line of evidence leading in the same direction is supplied by the continuity of the general plateau of the Cœur d'Alene Mountains with that of the Clearwater Mountains described by Mr. Lindgren and the relation of the latter to the main central Idaho batholith. This great plutonic mass must have solidified under a thickness of some thousands of feet of sediments, or other rocks, which with part of the granitic intrusion itself have been eroded away to form the undulating upland dissected by the Tertiary and present streams. It is highly probable that during this long period of leveling erosion the Cœur d'Alene region suffered a loss of material comparable with that stripped from the Clearwater region. The beds removed comprised the greater part of the Striped Peak formation and possibly overlying Algonkian and Paleozoic sediments of which no vestiges remain in the area studied.

Finally, the mineralogical character of the ore deposits suggests, on the whole, deep-seated precipitation, although most minerals which occur in ores form under such varied and complex conditions as to prescribe caution in their use as a means of determining original depth of deposition.

The available evidence, therefore, supports the view that the Cœur d'Alene ore bodies were formed at a time when the district was covered by a considerable thickness, perhaps amounting to several thousand feet, of rock which has since been removed.

## FUTURE OF THE DISTRICT.

Few districts have shown greater steadiness in production in the past or give promise of more long-continued activity than the Cœur d'Alene. It has been shown that the pay shoots extend to great depth with remarkably little change in the character of the ore. Some of the most productive mines are yet in their infancy so far as deep workings go. The Bunker Hill and Sullivan mine, which has paid over $9,000,000 in dividends, has hardly opened the ground below the level of the South Fork of Cœur d'Alene River and may reasonably be expected to continue its present rate of production for a score or more of years. The situation of this mine and the character of its ore indicate that the pay shoots now worked are high above the zone in which sphalerite and pyrrhotite may be expected to become abundant. The Morning and Hercules mines are also in a comparatively early stage of development and should continue productive for many years, although the relatively low grade Morning ore may show diminution in value at less depth than that of the Wardner mines. Some of the deeper Canyon Creek mines are apparently getting into lean ores and may cease to be profitable in a few years. On the other hand, new discoveries will undoubtedly be made in a district where such an ore body as that of the Hercules could remain unknown until a few years ago, and the total production of lead and silver is likely to increase for several years.

It should be pointed out that in estimating the future of any mine the nature of the country rock and the local geological structure should receive careful and detailed consideration. It is evident, for example, that an ore body inclosed by Revett quartzite known to be underlain by the Burke formation is in a far more advantageous geological situation than one placed near the base of the Burke beds.

In spite of the present activity of the Snowstorm mine, it is not probable that the district will ever become prominent as a source of copper. The zinc output, however, is likely to become larger and may possibly attain considerable proportions. The depth at which the lead-silver ores may be expected to become so sphaleritic as to furnish large quantities of zinc is, however, in most cases, so great that such ores would have to be mined at heavy expense for hoisting and pumping.

# CHAPTER V.—THE GOLD DEPOSITS.

## INTRODUCTION.

The general history of gold mining in the Cœur d'Alene region has already been summarized in Chapter I (pp. 78–81). The placer deposits near Murray were first worked early in 1884 and during the four years of greatest activity they probably produced about $1,500,000. Since the year 1889 this form of mining has greatly declined and in 1904 was represented by a little desultory hydraulicking in Dream Gulch, some "booming" on Trail Creek, and the operation of two or three dredges near Delta, on Beaver and Trail creeks. Quartz mining began nearly as early, in the Golden Chest, Mother Lode, and other mines close to Murray, and has suffered a similar decline, the production from this source in 1904 being practically negligible.

## GENERAL ACCOUNT OF THE GOLD-QUARTZ VEINS.

### DISTRIBUTION.

All the gold quartz veins hitherto exploited in the Cœur d'Alene district occur in the Prichard formation and most of them are within a radius of 2 miles from the town of Murray. The only known veins of any importance outside of this small area are those on Elk Creek and in Gold Run gulch, between Osburn and Kellogg.

The principal veins near Murray are those of the Golden Chest mine, situated on the north side of Prichard Creek, about a mile southeast of the town, and a group of three veins on the opposite side of the creek traversing what is known as Ophir Mountain (Pl. XV). On this group of veins are the Yosemite, Daddy, Mother Lode, Treasure Box, and Occident mines. Other mines which have in the past produced ore, although in comparatively small quantities, are the Gold King, situated on the south side of Prichard Creek, a mile west of Murray, the Buckeye Boy, on Dream Gulch; and the Crown Point, at the head of Trail Creek. Considerable work has been done also on Elk Creek, east of Kellogg, but these mines have long been abandoned and no information concerning them was obtainable in the year 1904.

### STRUCTURAL FEATURES.

The most common type of gold-quartz vein in the district is one which lies parallel to the planes of stratification in the slates and which may accordingly be referred to as a bed vein. As it happens that most of the veins are more nearly horizontal than vertical, the term blanket vein is also applicable to them in part. The veins in some places occur singly, but more commonly they are in groups, individual veins being separated by a few inches or a few feet of slaty country rock. An imbricated arrangement is common, one vein gradually pinching out while an overlapping vein between adjacent beds becomes correspondingly wider or thicker. Although some single veins may persist for hundreds of feet without cutting across the planes of stratification, such crossings may be observed here and there and crosscutting stringers of quartz linking neighboring bed veins are fairly abundant. Typical bed veins showing such crosscutting stringers are represented in Pl. XVI.

The veins as a rule are narrow and can be stoped only by the removal of considerable waste rock. Although a maximum width of about 10 feet is attained by one of the veins in the Golden Chest mine, the average width of all those that have been worked is probably nearer a foot. The contact between quartz and slate is sharp and usually unaccompanied by gouge. One of the veins in the Golden Chest mine, however, contains much triturated material due to movement along the fissure after the quartz was deposited.

Where the beds are thrown into sharp local folds the bed veins are also folded, as may be seen on the Martin level of the Golden Chest mine (fig. 14, p. 144) and in the Crown Point mine (fig. 15, p. 147). In both of these mines also the veins are dislocated by faults. Some of these are nearly vertical and cut the veins at large angles (see fig. 15), but at one place in the Golden Chest a bed vein has been ruptured and one part has been thrust over the other, as shown in Pl. XVI, by movement along the general plane of the vein, constituting a bedding fault. Most of these faults strike nearly north and south.

The only important fissure vein which cuts directly across the bedding of the slates is the Mead vein, on Ophir Mountain. This strikes N. 17° E. and dips 75° E. It is accompanied by two parallel bed veins shown in Pl. XV, which have furnished the ore to the Mother Lode, Treasure Box, and Occident mines. These bed veins lie east of the Mead vein and dip to the northwest at angles of about 18°. Their relation to the Mead is not shown in the underground workings and it is not known whether all three veins are of the same age or whether the Mead vein occupies a fault fissure which has cut the bed veins. The latter, so far as known, do not cross the Mead to the west. (See Pl. II, in pocket.)

A conspicuous banding, much of it very regular, is highly characteristic of the bed veins of the Murray district but is not found in those veins or stringers which clearly cut the planes of bedding. This banding is illustrated in Pl. XVI. As a rule, the narrower the vein the more regular and noticeable is this structure. In the wider veins the middle portion may be massive quartz and the banding may be confined to the parts of the vein near the walls. The banded appearance is due to the alternation of thin plates of quartz, usually a fraction of an inch in thickness, with much thinner sheets of dark material. In some places this dark material is a film of sheared slate, such as may be observed adhering to the side of the vein when a part of the wall rock is stripped away; but in many places the dark bands are due mainly to the presence of minute crystals of pyrite and other sulphides closely aggregated along parallel planes in the quartz.

The explanation of the banding which appears most in harmony with the facts is that the veins have been formed by successive small enlargements of the fissure, whereby the quartz previously deposited was separated from the wall with a film of slate adhering to the side of the vein. The fact that the cleavage of the slate is parallel to the vein accounts for the easy separation from the rest of the wall rock of the slate immediately attached to the quartz and for the absence of such banded structure in veins which cut across the edges of the beds. The banding is very similar to that found in some of the Mother Lode veins of California, which have Mariposa slate for country rock, and to which the same explanation has been applied.[a] In some parts of the vein the slaty material of the dividing films is still recognizable. In other parts, especially where the films were originally very thin, the development of sulphides, partly by replacement of the original film, has preserved the original banded appearance.

The microscope shows that in addition to the banding just described some of the quartz has a true ribbon structure, being traversed by microscopic cracks generally parallel with the walls of the vein. These cracks have a minute suture-like irregularity and cross the grains of quartz with little or no faulting. They are themselves here and there faulted, however, by other microscopic cracks transverse to the vein. Both sets of fractures, particularly the older, have afforded passage to solutions which have deposited small crystals of pyrite along them. These crystals almost invariably have diameters greater than the widths of the cracks and the pyrite has grown by replacement of the adjacent quartz. This ribbon structure is much less conspicuous than the banding due to successive reopenings of the vein fissures.

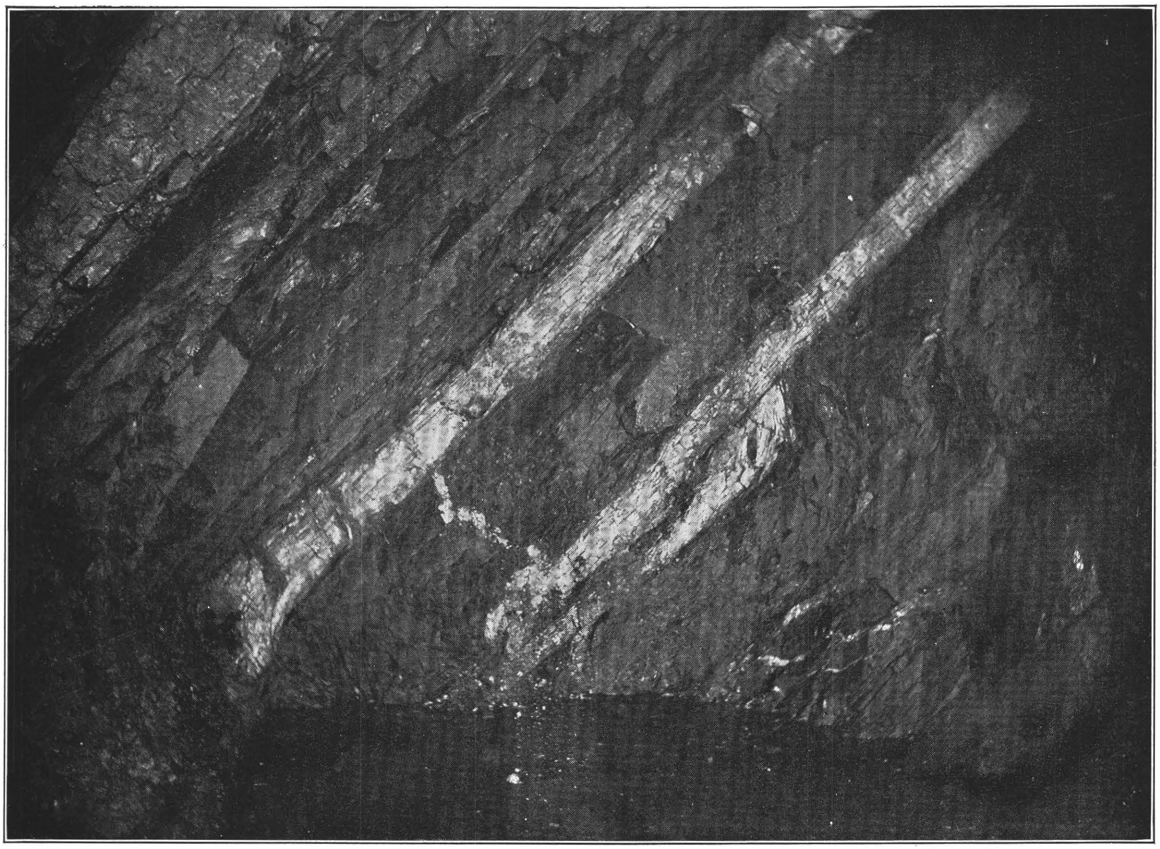
## THE ORE.

The material of the veins is a white quartz carrying variable proportions of pyrite, chalcopyrite, galena, sphalerite, and free gold. The pyrite is auriferous, but it is difficult in the present decayed state of the gold-mining industry to obtain satisfactory information regarding the tenor of the ores. According to a statement in the generally reliable "Cœur d'Alene Sun"

[a] Geologic Atlas U. S., Mother Lode district folio (No. 63), U. S. Geol. Survey, 1900, p. 7.

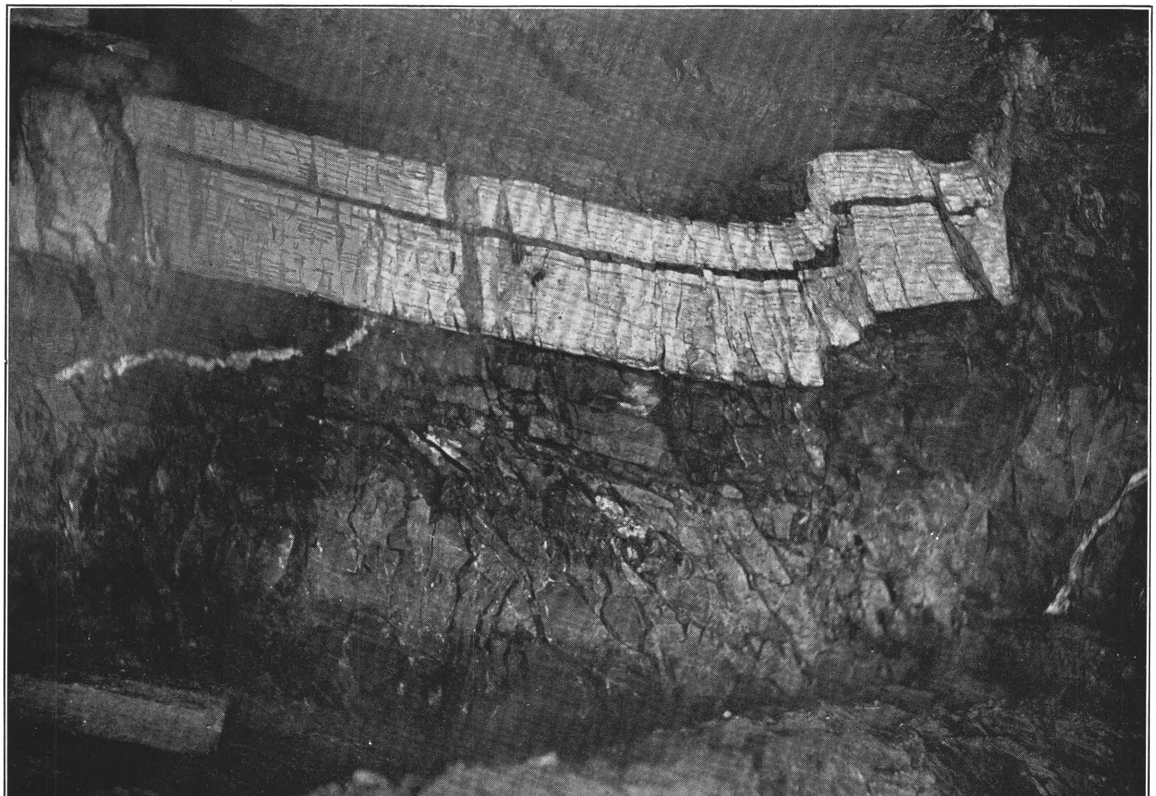
EASTERN PART OF OPHIR MOUNTAIN AS SEEN FROM THE NORTH, LOOKING ACROSS PRICHARD CREEK.

The two nearly parallel blanket veins outcrop along the face of the hill, rising toward the left. The lower one is first exposed near the creek, just east of the mill shown in the lower right-hand corner of the picture, and extends up through the notch in the crest of the spur. The upper one outcrops at the head of the long chute above the mill and can be traced diagonally across the slope by the line of small dumps and cuts.



*A.* PARALLEL BED VEINS IN PRICHARD SLATE, GOLDEN CHEST MINE.

Showing banded structure of veins and conformity with bedding of the country rock. The lower vein is faulted, being overthrust about 3 feet. A cross stringer connects the two veins.



*B.* A BED VEIN IN GOLDEN CHEST MINE.

Showing conformity with bedding of the slates. Banding is well displayed, and in one place a layer of slate an inch or two thick occurs in the quartz. A crosscutting stringer is visible below the vein. The apparent faulting on the right is due to foreshortening in the view, the vein dipping away from the observer.

of March 13, 1886, sulphurets from the Buckeye Boy afforded on assay 120.5 ounces of gold and 28 ounces of silver. The grade of ore in sight in 1904 was very much lower than that of the pockets formerly worked and probably nowhere exceeded $25 per ton. The Golden Chest at the time of visit was preparing to mill ore said to average $7 per ton.

One of the most interesting mineralogical features of the gold deposits is the presence of scheelite as a considerable although unevenly distributed constituent of the Golden Chest ore. (See Pl. XI, *D*, p. 100.) The material occurs in bunches. Some tons of fairly pure massive scheelite has been piled on the dump, and probably a still larger quantity has been thrown out mixed with waste. Although most of the tungsten used in steel making is obtained from the iron and manganese tungstates, wolframite and hübnerite, the calcium tungstate, scheelite, is also in good demand. As wolframite ore is at present worth from $8 to $9 per unit of tungsten trioxide and the scheelite contains a higher percentage of tungsten trioxide than the iron or manganese compounds, it is clear that the utilization of any considerable quantity of scheelite is well worthy of consideration. Although at present this ore brings a little lower price than wolframite, this is probably due to the fact that less of it has been marketed.

Outside of the occurrence of scheelite in one deposit, the Murray gold ores present no unusual mineralogical features. The prevailing gangue is quartz with no accompanying carbonates or silicates so far as known.

### AGE.

Beyond the fact that the veins are later than rocks of the Algonkian period, there is nothing to fix definitely the age of gold deposits. Inasmuch as they occur only in the Prichard slate, the oldest formation known in the district, it is possible that they were formed prior to the laying down of the Burke and subsequent formations. This, however, seems hardly probable in view of the unbroken sequence of sedimentation shown by the passage of the Prichard into the Burke and the absence of any evidence of unconformity within the entire Cœur d'Alene group. It is more likely that the restriction of the gold-quartz veins to the Prichard slates is due to some physical or chemical character peculiar to these beds, although it would be difficult to disprove the suggestion that the occurrence of the gold ores in the Prichard is merely a coincidence, the slates happening to be exposed by erosion over areas where the deposition of gold had been determined by deep-seated causes entirely independent of the rocks now visible at the surface.

Although the gold-quartz veins all carry a little galena, yet the striking feature about them is not their similarity to the lead-silver deposits but their rather marked difference in structure and in mineralogical character. No deposit has been found, so far as known, which suggests any transition between gold-quartz veins of the Murray type and lead-silver deposits such as those of the Barton and Paragon mines in the same (Prichard) formation. This difference, coupled with the fact that at least some lead-silver deposits occur in the Prichard, suggests that the two types of deposit correspond to different periods. The folding and faulting of the auriferous bed veins, as noted in the Golden Chest and Crown Point mines, leads to the further suggestion that the gold-quartz veins are older than the lead-silver veins and were perhaps formed under a greater load of overlying sediments. The ore was probably deposited before the rocks had been greatly deformed and before the opening of the fissures which served as channels for the lead and silver-bearing solutions.

### FUTURE OF GOLD MINING.

It can not be said that the outlook for any extensive revival of quartz mining in the Cœur d'Alene district is very bright. The veins are small and although they contain pockets of rich ore, much of the quartz is of very low grade and the deposits are lacking in the large bodies of medium-grade ore which would warrant operations on an extensive scale. The low dip of most of the veins and the complications introduced by the folding and faulting of the ore also stand in the way of extensive or long-continued operations, such as give stability to the mining industry based on the lead-silver deposits of the district.

## DESCRIPTIONS OF GOLD MINES.

### GOLDEN CHEST MINE.

*Introduction.*—The Golden Chest, the largest gold mine in the district and one of the first to be successfully worked, is situated in Reeder Gulch a mile east of Murray. In 1885 about 25 men were employed and the ore was treated in a 10-stamp mill. In 1900 the mine was sold for $25,000 and shortly afterward the Idaho, Katie, and Dora claims were acquired by

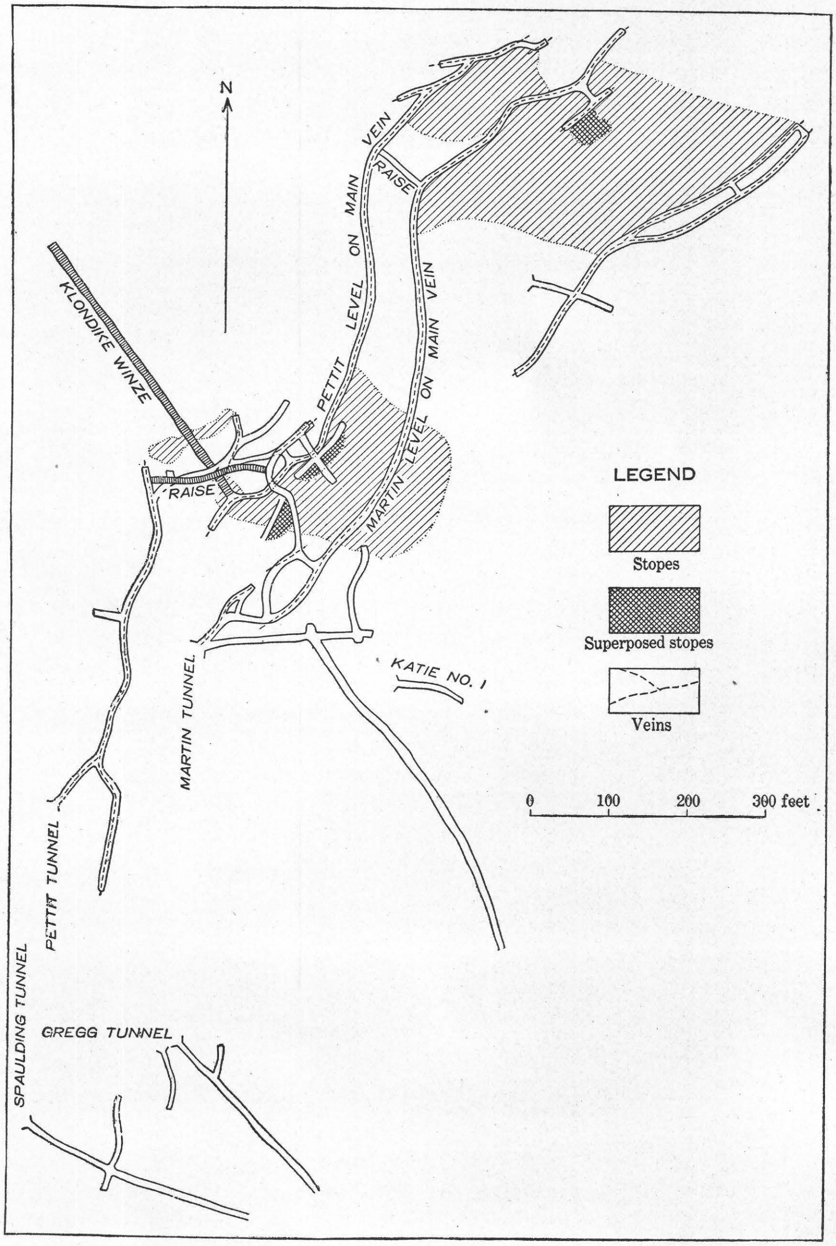



FIG. 14.—Sketch plan of principal workings of the Golden Chest mine.

the Golden Chest Company. A 20-stamp mill was erected on the Idaho property in 1892, but was scarcely used. The machinery was afterward utilized in the reconstruction of the original Golden Chest mill.

Although considerable work has been done in the Golden Chest mine, operations have been very desultory and seasons of activity have alternated with long periods of idleness.

Frequent changes of ownership have been partly responsible for the lack of continuous and systematic exploitation, but the principal explanation of the mine's history is probably summed up in the statement that effort has been directed to the extraction of comparatively small rich shoots and that the ore thus mined has been milled with crude equipment. At the time of visit, in 1904, the mill was being overhauled preparatory to a resumption of mining by a new company.

*Development.*—There are four tunnels in Reeder Gulch which are driven for the most part along the lode. The most important of these, the Pettit tunnel, shown in fig. 14, is about 1,200 feet in length. An inclined winze, about 300 feet in length, the Klondike winze, has been sunk below this tunnel but was partly filled with water at the time of visit. Another tunnel, known as the Idaho tunnel, not shown in fig. 14, has been run on the lode from a point on the main road just west of Littlefield. (See Pl. I, in pocket.) This tunnel, about 1,000 feet long in 1904, was intended to connect with the winze just mentioned. Two pay shoots, ranging from 200 to 300 feet in stope length, have been stoped from the Pettit tunnel practically to the surface and some ore has been taken from the winze.

*The lode.*—The ore-bearing zone conforms in general to the strike and dip of the Prichard slate, which is the country rock of the mine. It strikes generally about N. 15° E., but is variable in trend. The dip is from 40° to 45° W. The rocks, however, form a sharp local syncline, the ore being in the eastern limb, and the dip of rocks and veins may undergo considerable change at moderate depth.

Within this zone there are at least six quartz veins. The westernmost one, which is the one followed by the first 400 feet of the Pettit tunnel, is rather irregular, consists of many stringers, and is a good deal disturbed by movement subsequent to the deposition of the quartz. This vein in places cuts the locally contorted beds of slate and apparently corresponds to a plane of notable faulting. The vein followed in the Idaho tunnel is similar in character and may occupy the same fissure. The movement along this fissure has evidently been long continued, as quartz of an early period of deposition has been fractured and veined with pyrite.

Lying east of this vein on the Pettit level are veins showing much less disturbance and more closely conforming to the bedding of the country rock. The one from which most of the ore has been obtained lies about 150 feet east of the westernmost vein where the two are crosscut on the Pettit level. It ranges in width from a few inches up to 10 feet. The narrower portions, up to a foot in width, are as a rule finely banded, thin plates of white quartz alternating with dark films or sheets of slate. (See Pl. XVI, p. 142.) The parts of the vein showing banding are invariably parallel to the bedding of the slates, this structure being absent from those parts of the vein or from stringers that cut across the slate laminæ. The wider parts of the vein show no banding and apparently occur in places where the country rock contains beds of quartzite. This brittle rock was shattered by the original fissuring and the quartz has partly filled open spaces and partly formed by recrystallization or replacement of the quartzite fragments.

On the Martin level, probably about 50 feet above the Pettit level, the slates in the hanging wall of the principal stopes show more disturbance than those below and are cut in many directions by stringers and bunches of quartz. Some of these, which follow the bedding of the slates and are banded like the main vein, have been sharply folded and crumpled. As the quartz is not crushed, it would seem to have been deposited after the slates were folded, although it is difficult on this supposition to see how fissures of fairly regular width and conformable to the laminæ of the slate could have been opened subsequent to the crumpling of the country rock.

The individual veins which make up the Golden Chest zone are not very persistent, with the possible exception of the one which shows the most evidence of faulting. The regular sheets of banded quartz can in places be followed for several hundred feet, but eventually they gradually pinch out and may be succeeded by an overlapping vein a few feet within the hanging or foot wall. Linking stringers of quartz between the thin edges of two such quartz lenses are common.

As a rule the veins lying east of the main fault fissure show little or no disturbance of the quartz and are unaccompanied by gouge. In one place, however, on the Pettit level, movement along the plane of the vein has thrust one part of the quartz filling over the other for 3 or 4 feet, as shown in Pl. XVI.

*The ore.*—The usual ore of the Golden Chest mine consists of white quartz carrying pyrite, galena, and sphalerite.. Some specimens show chalcopyrite also. The sulphides are in many places intimately intergrown and galena and sphalerite may be inclosed in pyrite. Free gold is not usually visible but may be seen here and there associated with the sulphides.

A peculiar feature of the Golden Chest ore is the presence of massive pale-brown scheelite in bunches in the ore shoots, particularly in the winze below the Pettit level. It is intimately associated with the quartz and like that mineral incloses the various sulphides found in the vein. (See Pl. XI, *D*, p. 100.) Owing to its high specific gravity the scheelite is not sent through the mill, but is sorted out and thrown aside. Whether the sulphides embedded in it contain as much gold as those in the quartz is not known.

The ore is apparently of rather low grade on the whole, the tenor of that sent to the mill being given as about $7 to the ton. It is said that much of the ore formerly mined carried from $70 to $90 in gold to the ton.

## OPHIR MOUNTAIN MINES.

The Yosemite, Daddy, Mother Lode, Treasure Box, and Occident mines are all situated on the south side of Prichard Creek about a mile southeast of Murray, on the steep slope locally known as Ophir Mountain (Pl. XV, p. 142). All were active though somewhat erratic producers up to a few years ago, but in 1904 the only work in progress was some development in the Yosemite. In the eighties the Treasure Box, Occident, and Mother Lode produced considerable ore from rich pockets, which was worked in arrastres. In 1887 the Treasure Box was cleaning up as much as $10,000 a week in this manner and arrastres continued to be used until about 1892. The average tenor of the ore treated in 1891 was about $30 a ton but much richer ore was obtained prior to this, an arrastre run of 30 tons of Mother Lode ore in 1890 averaging $92 a ton. In 1889 a 5-stamp mill was erected to treat the Mother Lode ore, and in 1894 a similar mill was built for the Daddy mine. The Yosemite mine first came into notice about 1893 and has produced in all about $500,000. It has a 10-stamp mill built in 1895 but not now used.

There are three important veins in this group. One, known as the Mead, strikes N. 17° E. and dips 75° E. This is a typical fissure vein which cuts across the bedding of the Prichard slate. Although rarely over a foot in width, it has furnished most of the production of the Yosemite mine. The vein consists of white quartz carrying pyrite, chalcopyrite, galena, and sphalerite. It is not banded. The workings on this vein consist of tunnels, the lowest being over 200 feet above Prichard Creek. A little ore, worth about $25 per ton, was in sight in 1904.

East of the Mead vein are two nearly horizontal or blanket veins lying one above the other in the planes of stratification of the Prichard slate. The upper one, which has supplied most of the ore from the Mother Lode, Treasure Box, and Occident mines, appears to be cut off by the Mead vein on the west, about 150 feet above Prichard Creek. From this point the outcrop can readily be followed by the line of stopes and tunnels (see Pl. XV) along the hillside up to the Occident workings, on the spur just west of Littlefield. The lower blanket vein is about 200 feet vertically below the upper one and approximately parallel to it. The general dip of the veins and beds is about 18° NW. As a rule the veins are narrow and much of the ore stoped was less than a foot in width. On both veins, stopes have been carried irregularly in from the surface, although as the workings are not mapped and only in part accessible it is not known how far into the hill the old stopes extended—probably not over 300 feet. As is usually the case with the bed veins in the Prichard slate, these on Ophir Mountain are not very persistent but pinch out and are succeeded by other overlapping veins in different stratigraphic planes.

The quartz of the blanket veins is generally banded, sheets of white quartz being separated by thin films of slaty material, or of sulphides. The banding is as a rule more noticeable in the narrower parts of the veins and near the walls. The contact between the vein and the inclosing slate is sharp and shows little or no gouge. The metallic constituents consist of pyrite, galena, and free gold. Sphalerite and chalcopyrite are probably also present, although they were not observed in the specimens collected. The sulphides in general appear not very abundant and in the comparatively lean ore examined at the time of visit occur mainly in small crystals in the dark films which give the quartz its banded appearance.

### BUCKEYE BOY MINE.

The Buckeye Boy is a small mine in Dream Gulch, a mile west of Murray. The vein appears to have been first worked in 1885 and a single pocket of rich ore produced about $25,000, the ore being crushed by hand in mortars. There are apparently several nearly horizontal veins of the usual banded quartz typical of the Murray deposits, lying in much folded and disturbed Prichard slate. The old stope whence the rich ore was obtained is no longer accessible and no detailed examination of the property could be made in 1904. The principal vein averages from 6 to 8 inches in width but expands in places to 5 feet. As is usual in these veins, the banding is most distinct in the narrow portions.

Some of the ore taken from this mine carried 550 ounces of gold and 140 ounces of silver to the ton. Specimens in the possession of Mr. Adam Aulbach, of Murray, show abundant coarse free gold associated with galena, sphalerite, and pyrite in a quartz gangue. The shoot whence this ore came is said to have been of circular plan and about 25 feet in diameter, the rest of the vein being comparatively barren.

The mine was idle at the time of visit, although some of the quartz mined in former years was being run through a 2-stamp mill.

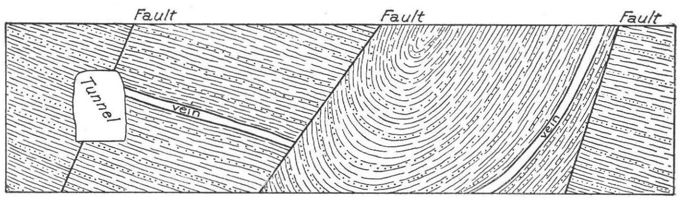


FIG. 15.—Diagrammatic sketch showing folding and faulting of Crown Point vein. Not drawn to scale.

### CROWN POINT MINE.

The Crown Point prospect, at the head of Trail Gulch, was opened about 1898 on one of the usual banded bed veins of the Murray district. The vein strikes nearly north and south and, where followed by the tunnel, dips 15° to 20° E. The tunnel follows a fault which cuts off the vein on the west. A short distance east of the tunnel are other north-south faults and the slates and vein are sharply folded. These relations are shown diagrammatically in fig. 15. The faulting, and probably the folding also, took place after the quartz was deposited.

The quartz carries pyrite, galena, sphalerite, chalcopyrite, and probably free gold, as some of the ore has been worked by hand in mortars.

### NEW JERSEY MINE.

The New Jersey property is situated near the mouth of Gold Run gulch, about 2 miles east of Kellogg, on a large vein of massive white quartz. The vein, which outcrops boldly, strikes about northwest and dips 75° SW. Both strike and dip, however, are rather variable. The vein is in places 14 feet wide and sends off at least two large spurs to the northeast, one of which rapidly narrows away from the main vein and pinches out within a distance of 40 feet. The country rock is Prichard slate.

This vein was not being worked in 1904. A 10-stamp mill had recently been completed to treat the ore, but its operation was not successful and change to a cyanide plant was being discussed.

The material of the vein is a white, rather glassy quartz containing little bunches of pyrite and specks of tetrahedrite, chalcopyrite, galena, and sphalerite.

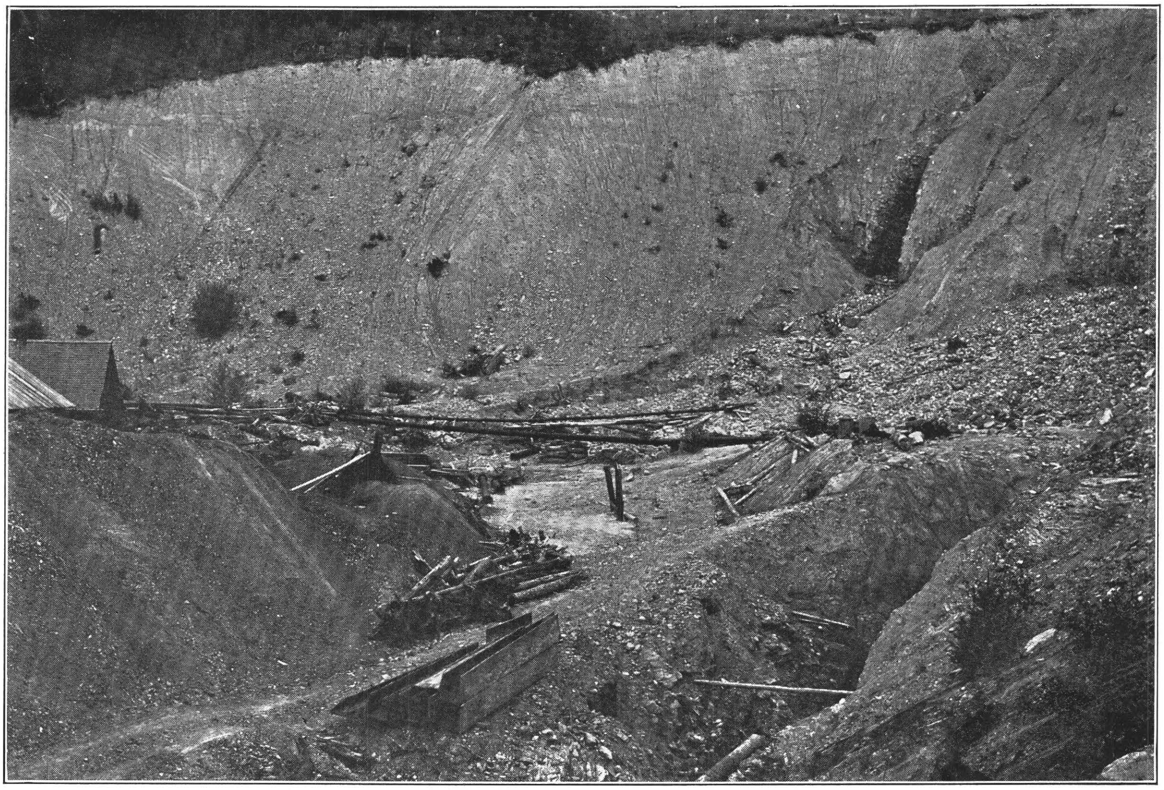
## PLACERS.

The auriferous gravels, which first drew miners into the Cœur d'Alene region, are situated in the part of the district drained by Prichard and Beaver creeks, tributary to North Fork of Cœur d'Alene River. They fall chiefly into two classes—bench gravels or remnants of former stream channels, now perched high on the hillsides, and the alluvial deposits of the present stream beds. The latter were the richer, were first worked, and have been nearly exhausted. They were exploited mainly by panning and sluicing. The bench gravels are of lower tenor and have been worked by hydraulicking.

The most productive bench gravels are those locally known as "the old wash," illustrated in Pl. VI, *B* (p. 34). They form a chain of deposits on the north side of Prichard Creek near Murray and were evidently once the continuous bed of a stream ancestral to Prichard Creek at a period when the region was less deeply incised by erosion than at present. As shown in Pl. I (in pocket), the easternmost patch of these gravels now preserved lies between Wesp and Cougar gulches, about a mile east of Murray, and approximately 400 feet above Prichard Creek. A larger remnant, which has been extensively hydraulicked, is situated between Alder and Buckskin gulches, at an elevation of about 250 feet above Prichard Creek. The older gravels on the sides of Dream Gulch have about the same elevation above the present main valley. From this point westward they spread out toward Eagle Creek and it is difficult to recognize the exact course of the old trunk channel, as some of the remnants of gravel were probably deposited by tributary streams. So far as can be judged from residual patches of gravel which may not have been deposited quite simultaneously and all of which may not correspond to the line of greatest depth of the old channel, the ancestral stream had a steeper grade than the present Prichard Creek. It is probable, however, that the contrast in grade has been increased by regional tilting since the older stream abandoned its channel.

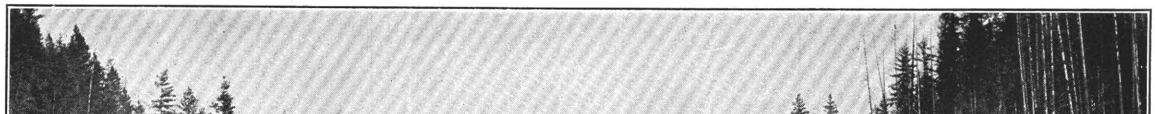
It is of interest in this connection to consider the bench gravels along the South Fork of the Cœur d'Alene, although these, so far as known, are not sufficiently auriferous to be worked. From the vicinity of Wallace westward beyond the boundary of the area mapped (Pl. II, in pocket) is a chain of gravel deposits which evidently corresponds to an older stream having nearly the course of the present river. Just north of Wallace these gravels attain an elevation of 1,000 feet above the South Fork, but at Kellogg the difference in altitude is only about 200 feet. These figures are necessarily only approximate, as the masses of gravel are not everywhere well exposed and it is possible at but few localities to determine the deepest point in the old channel. In some places the gravels were probably reworked in part and left at successively lower levels as the river cut down its bed. The differences in elevation noted, however, indicate that the ancestral South Fork, from Wallace westward, had a steeper grade than the present stream. There are extensive gravel terraces near Mullan which extend from the river to elevations as great as 400 feet above the present stream. These, however, are at too low an altitude to be part of the old channel west of Wallace unless the region has suffered greater deformation in late Tertiary and Quaternary time than is suggested by any other line of evidence. It is probable that these Mullan gravels are related to a later phase in the erosion of the present valley.

The gravel of "the old wash" near Murray is in places fully 100 feet thick. The older workings as a rule do not afford good exposures of the deposit, as their banks have become disintegrated and are already partly overgrown by vegetation. In Dream Gulch, however, where some hydraulicking has recently been in progress (See Pl. XVII, *A*), fresh sections of the gravel were visible in 1904. The material is unstratified. The largest bowlders, some being 5 feet in diameter although few are over 2 feet, occur in the lower 20 feet and the gravel becomes gradually finer toward the top. The bowlders and pebbles consist mainly of quartzite, although those of syenite and of banded siliceous slate from the upper part of the Prichard are abundant. They are remarkably well rounded and appear at first glance to be hard and sound. All, however, are more or less decomposed and, although still retaining their polished surfaces, can be picked to pieces. Most of them soon crumble to sand when exposed to the weather. They are embedded in a firm but not hard matrix of sandy yellow clay and are much more easily washed than the typical auriferous gravels of the Sierra Nevada.



*A.* HYDRAULIC WORKINGS IN BENCH GRAVELS, DREAM GULCH.

The trench in the foreground is in decomposed Prichard slate.



*B.* FANCY GULCH, 3 MILES NORTHWEST OF MURRAY.

A typical gulch in which the recent gravels have been washed.

The material of these gravels shows that they have been transported from the region now drained by the headwaters of Prichard Creek. The gold, however, has probably not come so far but has been concentrated from the quartz veins and stringers in the Prichard slate near Murray. The Golden Chest and Mother Lode veins, as well as countless small stringers and pockets in the slates, have probably all contributed gold to the older gravels, partly under direct attack of the hard bowlders on the fissile bed rock of the old river and partly with gravel and disintegrated rock washed into the main stream from side gulches.

West of Dream Gulch the bench gravels appear to attain a thickness of about 300 feet, but they have been very little worked and practically nothing is known of the configuration of the rock floor upon which they rest.

The recent gravels of Prichard and Beaver creeks and their tributaries (Pl. XVII, *B*) have derived their gold partly from the older, probably Tertiary gravels and partly from the slates disintegrated in the cutting of their modern valleys or ravines. They represent the final stage in a process of natural concentration and were far richer than the bench gravels. Practically all the side gulches along Prichard Creek, from Eagle on the west to Raven on the east, were scenes of much activity in the early days of mining, the richest gravels being in those gulches north of Prichard Creek and south of Eagle Creek which have been cut down through the "old wash." Dream Gulch, a mile west of Murray, was particularly rich, the gold of the recent gravels being partly derived from the older gravel deposit and partly from the eroded portions of the Buckeye Boy and other quartz veins in the slate. The best claims in Buckskin and Dream gulches yielded from $2 to $20 to the pan.

One of the most famous placers near Murray was the Widow, situated at the east end of town. It was located by Prichard and was the object of bitter legal contests for several years. Another prominent claim was the Gillett, half a mile west of Murray, which in 1885 had produced about $25,000 from a single acre. The other 19 acres have never been worked.

Trail Creek and its branches contained some of the richest gravel formerly worked, the Myrtle placer claim on that creek being famous as a source of large nuggets. Much of the gravel on this creek, especially near Delta, is from 18 to 20 feet thick and was worked by sinking shafts to bed rock and then drifting. Near the headwaters, however, in the vicinity of Thiard, the gravel, much of it consisting of imperfectly rounded fragments from the adjacent slopes, was panned or sluiced. At Thiard are some benches of gravel rising to heights of 20 to 30 feet above the present stream bed, and thus somewhat older than the most recent deposits. This gravel has been washed on a small scale and is apparently not rich.

At present a few thousand dollars' worth of gold is obtained annually from the Trail Creek gravels near Delta by booming. In this method the water is impounded in a reservoir fitted with an automatic discharge gate. When the reservoir is full the gate opens, and the whole body of water is directed against the gravel in such a manner as to wash it away. A small stream is thus rendered far more effective than if it were continuously employed. When the gravel has been removed within about 2 feet from bed rock the remainder, which is the auriferous portion, is shoveled into sluices.

There were three dredges in the district in 1904, two on Beaver Creek and one on Trail Creek at Delta. Those on Beaver Creek were not very successful and one was being taken apart for shipment to Oregon. The one on Trail Creek was making a profit on gravel averaging about 10 cents to the yard.

The present bed of Prichard Creek has been worked, about a mile west of Murray, by a hydraulic elevator; but the depth of the gravel, in many places fully 30 feet, has hitherto proved an insurmountable obstacle to the extensive exploitation of this deep channel. The gravel is too low to be hydraulicked and too deep for dredging. It could probably be worked only after the water of Prichard Creek had been diverted or flumed.

The placer gold of the younger gravels near Murray is coarse, nuggets up to 40 ounces in weight having been found. The nuggets are usually somewhat rough or hackly and many of them contain some of the quartz in which they were originally embedded. The gold ranges in value from $15 to $18 an ounce. The total production of placer gold in 1905 amounted to about $50,000.

## CHAPTER VI.—THE COPPER DEPOSITS.

### INTRODUCTION.

What is commonly referred to as "the copper belt" of the Cœur d'Alene district is an area which is not susceptible of precise delimitation but which lies east of a meridian through Stevens Peak and south of Canyon Creek, thus being in the southeast corner of the district. (See fig. 3, p. 84.) How far south it extends, beyond the area shown on Pl. I (in pocket), is not known. Within this belt are one productive mine, the Snowstorm, and several prospects. At the time of visit in 1904 the Snowstorm had produced about $60,000. In 1906 the production had risen to 82,679 tons for the year, with a gross value of $1,069,324.[a] The improvements in 1905 and 1906 cost $152,350, and the net profits amounted to $150,000.

The deposit of the Snowstorm mine consists of disseminations of bornite, chalcocite, and chalcopyrite in certain beds of the Revett quartzite. The greater part of the sulphides, however, has been oxidized to cuprite and malachite. The various prospects are on metasomatic fissure veins carrying chalcopyrite, chalcocite, or bornite, with quartz, dolomite, or siderite.

### THE SNOWSTORM MINE.

*Introduction.*—The Snowstorm mine, which has lately come into prominence as the only producer of copper ore in the district, is situated near the head of Daisy Gulch, 3½ miles east-northeast from Mullan, the principal adit being at an elevation of approximately 5,100 feet. Work on this property began in November, 1903, and at the time of visit the mine had been well opened for stoping and was connected with the railway at the mouth of the gulch by a Riblet aerial tramway. A leaching mill was also in process of construction at the lower terminus of the tramway. The total production of the mine in August, 1904, amounted to about $60,000, practically all from development work. The mine, except the lower tunnel, which is not yet producing ore, was then worked by lessees who had constructed the tramway.

The leaching mill has since been successfully operated, the process being reported as follows:[b]

> An extraction of about 97 per cent is said to be obtained at the Snowstorm mill at Larson, Idaho, where a copper carbonate ore is being treated. After crushing, the ore is run into agitators, where it is mixed with a 10 per cent solution of sulphuric acid and a solution of chloride of lime. Thus a solution of copper sulphate is formed, while the silver remains as a precipitate of chloride. From these agitators, which are three in number, the copper sulphate solution goes through a series of six settling vats. From the solution, the copper is precipitated with scrap iron, and the residues containing the silver chloride are treated with sodium thiosulphate. The solution of silver thiosulphate thus obtained is passed through settling vats and the silver is precipitated from the clear solution by sodium sulphide, the precipitate being filtered and shipped for refinement. The ore runs from 2½ to 3½ per cent copper and about 7 ounces silver.

*Underground development.*—The Snowstorm mine, as shown by figs. 16 and 17, is opened by three tunnels which crosscut northeast to the ore. The middle or No. 2 tunnel is the most important and is the one from which ore is being shipped. No. 3 tunnel has reached the lode, which has been explored for about 400 feet on this level. No workable bodies of ore had been found in this tunnel, however, at the time of visit.

*Form of deposit and geological relations.*—The Snowstorm lode is a zone of impregnation which embraces one or more beds of the Revett quartzite and conforms to the bedding of the rocks in which it lies. It strikes N. 60° W. and dips to the southwest at an angle of 65°. In some places the zone of mineralization is 40 feet wide. There is apparently no lithological

[a] Statement to county assessor.

[b] Min. and Sci. Press, June 22, 1907, p. 782.

difference between the quartzite that carries the ore and that which forms the country rock. Neither is there any pronounced or persistent fissuring along the lode, such as might be supposed to have determined ore deposition in its vicinity. The ore occurs impregnating the apparently unfissured quartzite, and along joints and small irregular fractures. Microscopic study shows, however, that the quartzite has been crushed and that it is traversed by a network of microscopic fractures. (See Pl. XI, *E*, p. 100.) These capillary openings, invisible to the unaided eye, gave access to the ore-bearing solutions. The deposit as a rule has no definite walls, although the ore is locally limited by bedding planes in the quartzite.

All the upper workings are in the Revett quartzite. No. 3 tunnel, however, as shown in fig. 17, enters in the slaty rocks of the St. Regis formation. About 100 feet south of the lode this tunnel passes through a well-defined fault breccia into the Revett quartzite. As the St. Regis is stratigraphically above the Revett, the fault is clearly a reverse or thrust fault. The throw is unknown but can not be less than 700 feet. As fig. 17 shows, the fault must cut the ore-bearing zone only a short distance below the tunnel. The fault shows no mineralization and contains about 10 feet of clay gouge. These facts would ordinarily be taken to indicate that the fault is later than the ore. In this district, however, such a conclusion can not safely be drawn and the relative age of fault and ore must remain for the present undetermined. In any event it is unlikely that the present ore body can be followed for much more than 100 feet below No. 3 tunnel.

In No. 2 tunnel the ore shoot is at least 500 feet long, although the ore in the faces of the drift at the time of visit was of low grade. In No. 3 tunnel, as already mentioned, no ore bodies of commercial importance have yet been found.

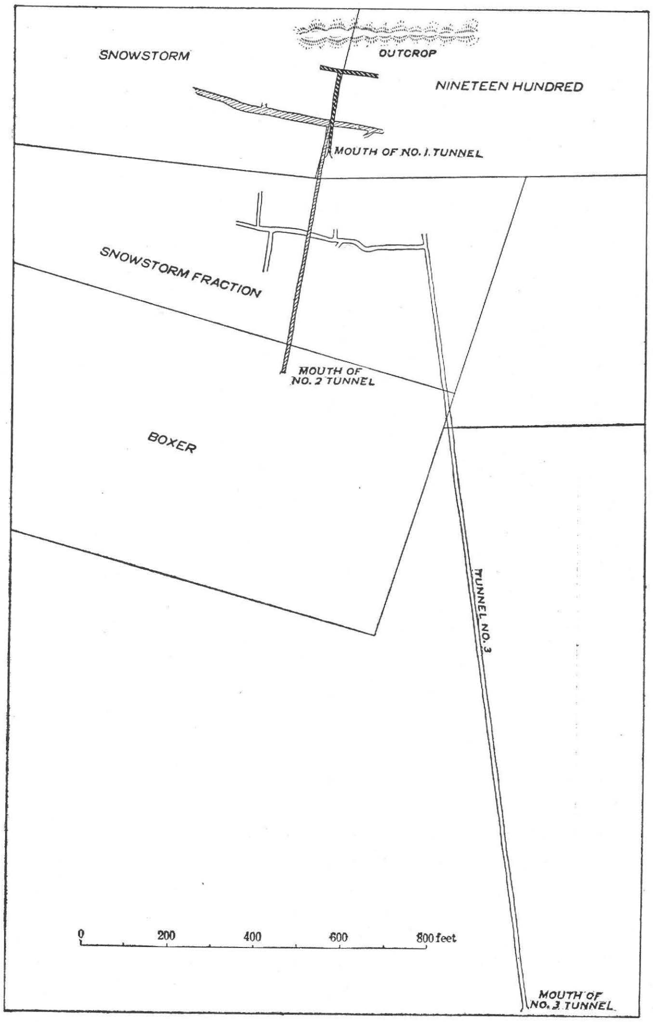



FIG. 16.—Plan of the underground workings of the Snowstorm mine.

*The ore.*—In its unoxidized form the best ore consists of quartzite so crowded with little specks and small irregular bunches of bornite, chalcocite, and chalcopyrite as to be dark gray or nearly black. The microscope shows (Pl. XI, *E*) that the ore minerals to some extent fill irregular microscopic fissures but that for the most part they have replaced the interstitial sericite and siderite of the country quartzite.

Comparatively little of the ore, however, remains in its sulphide condition. Most of it has been oxidized to cuprite and malachite. There is no well-defined zone of oxidation, most of the sulphide ore occurring in No. 2 tunnel and some carbonate in No. 3 tunnel. The latter tunnel is very wet, a large flow of water having been encountered as soon as the quartzite was cut. This water, however, evidently comes from the surfaces of the neighboring ridges and is oxidizing in its character. It is held in all the fissures in the brittle quartzite and is dammed on the southwest by the clay gouge of the fault.

The average tenor of the ore, as shipped in 1904, was 4 per cent of copper, with about 6 ounces of silver and 0.1 ounce of gold per ton. One carload shipped carried 12½ per cent of copper and 15 ounces of silver, no returns being made for gold. Another shipment contained 8.7 per cent of copper, 13½ ounces of silver, and $2.60 in gold, per ton. Most of the ore at the time of visit was being shipped to Butte, Mont., in accordance with a stipulation that the silica should not fall below 90 per cent.

## PROSPECTS.

*Copper King.*—The Copper King prospect is near the head of Sonora Gulch, about 2½ miles northwest of the Snowstorm mine. The country rock is banded sericitic quartzite and belongs to the Revett formation. The workings, consisting of a tunnel, follow a fissure striking N. 70° E. and dipping 75° S. The fissure, which is narrow and shows a little gouge, contains scattered bunches of tetrahedrite and chalcopyrite. Some small irregular stringers near the main fissure are filled with quartz, galena, and chalcopyrite and the country rock carries small

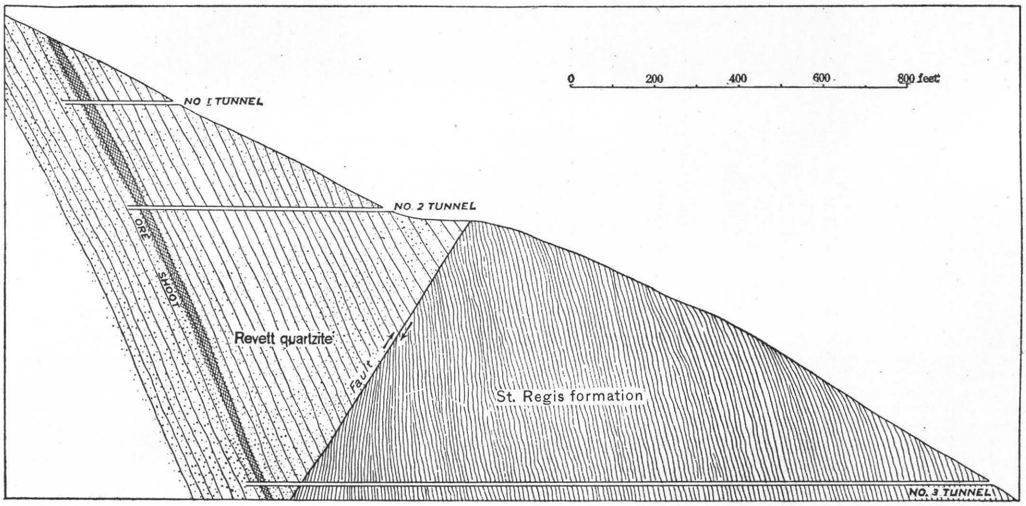



FIG. 17.—Cross section through the Snowstorm mine, showing the geological relations of the ore body.

specks and seams of bornite and chalcopyrite. None of these minerals, however, had been found in sufficient quantity to constitute ore when the prospect was visited.

*Silver Cliff.*—The principal tunnel on the Silver Cliff prospect is half a mile north of Lookout station, the highest point on the Northern Pacific Railway east of Mullan. The vein, which cuts striped, greenish slaty rocks belonging to the St. Regis formation, strikes north and south and dips to the east at 70°. It is a distinct fissure containing stringers of ore which have been dislocated by some movement along the fissure since the ore was deposited. There is no replacement of country rock by the ore, which consists of quartz and dolomite carrying chalcopyrite and bornite. A little galena has also been found in small bunches in the country rock.

No ore has been shipped nor has any mass of commercial size been discovered. The developments at the time of visit comprised two tunnels, the lower being a crosscut of 1,500 feet to the vein.

*Stevens Peak.*—The dark banded quartzites of the Wallace formation are traversed on East Fork of Willow Creek, about a mile north of Stevens Peak, by a nearly east-west fissure with steep dip to the south. The Stevens Peak and Reindeer prospects are both on this fissure, the former being on the east side of the stream. The croppings at the Stevens Peak show from 3 to 4 feet of soft limonite, probably altered siderite, traversed by stringers of quartz which carry a little chalcopyrite. Over 1,400 feet of work has been done, but apparently not to the best advantage. The vein is bunchy, consisting of stringers of siderite and quartz, with no galena.

*Park.*—South of Stevens Peak, and probably less than half a mile outside of the area here mapped, is a zone of east-west fissuring in fine-grained, banded sericitic quartzite belonging to the Wallace formation. The Park vein, the principal member of this zone, is of variable width and has no well-defined walls. The dip is practically vertical. The lode has been prospected by three or four tunnels, which show it to be a metasomatic fissure vein in which the ore, consisting of pyrite and chalcopyrite in a siderite and quartz gangue, in part replaces the shattered quartzite and in part fills what were once open spaces. The ore contains some chalcocite which is probably secondary, as it is associated with oxidized ore.

The ore, which would require concentration, is said to contain $3 in gold and 10 ounces of silver to the ton, in addition to the copper. No shipments had been made in 1904.

The Springfield, another prospect lying west of the Park and said to be on the same vein, was not visited.

## CHAPTER VII.—DETAILED DESCRIPTIONS OF THE LEAD-SILVER MINES NEAR WARDNER.

### SITUATION.

The principal mines near Wardner are distributed along a west-northwest and south-southeast zone which extends from Milo Creek, half a mile south of Wardner, to the little settlement of Silver King, in Government Gulch, just outside of the area mapped. They comprise the Bunker Hill and Sullivan mine, embracing over 100 claims, owned by the Bunker Hill and Sullivan Mining and Concentrating Company; the Last Chance mine,[a] owned by the Federal Mining and Smelting Company; the Sierra Nevada mine, owned in part by the Federal and the Bunker Hill and Sullivan companies; and the Crown Point and Silver King mines, owned by the Cœur d'Alene Development Company.

In spite of different ownership the workings of these mines (see Pl. XIX), particularly of the Bunker Hill and Sullivan, Last Chance, and Sierra Nevada mines, are so involved and so related to a common fissure system that they are most conveniently described together.

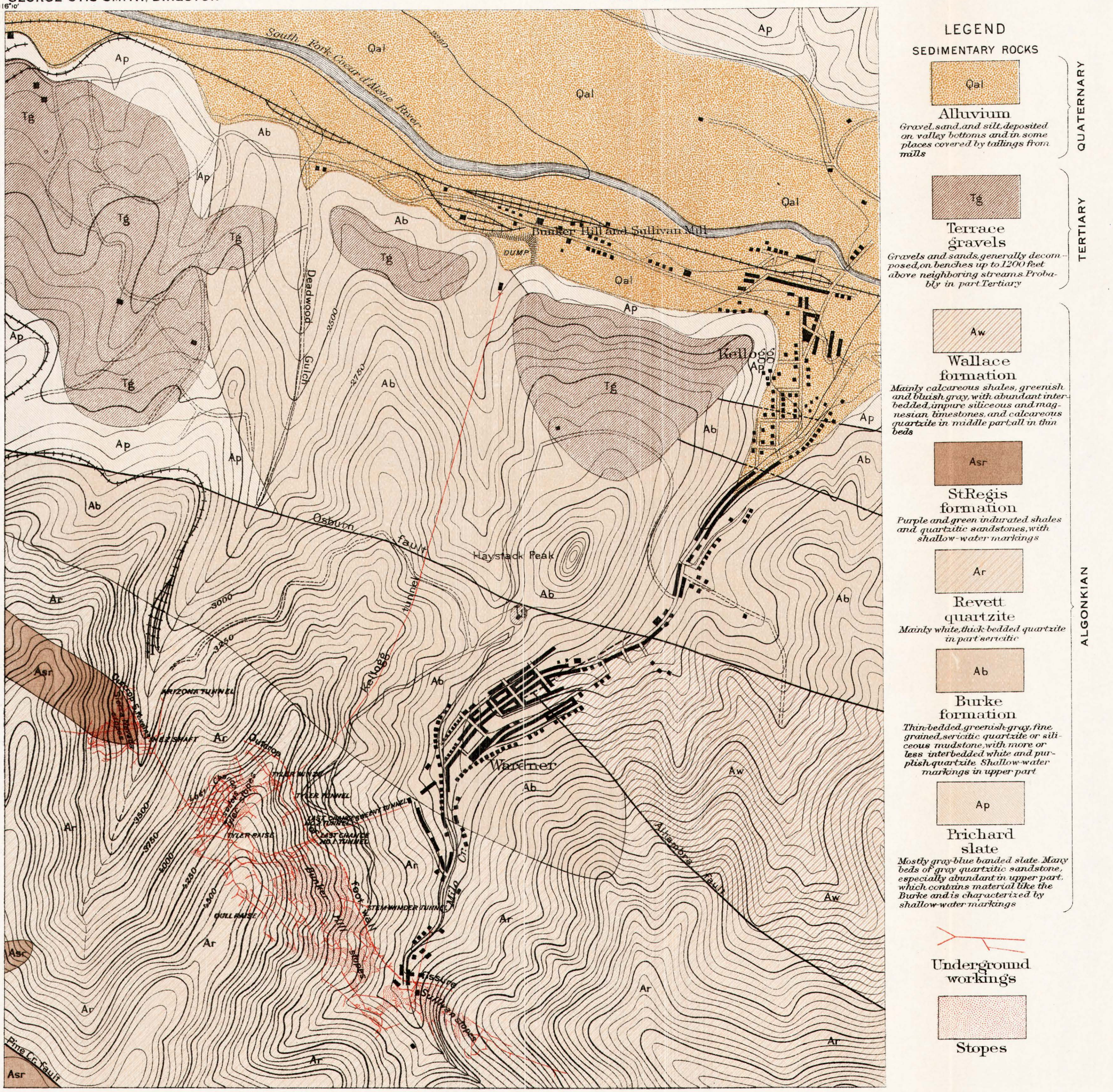
An idea of the general relative positions of the mines may be had from Pl. XVIII and XIX. On the steep slope east of Milo Creek are the old upper tunnels of the Sullivan mine, shown in Pl. XX, *A*. On the western side are the upper workings of the original Bunker Hill mine, along the line of the inclined tramway seen in Pl. XX, *B*. North of the tramway and shown almost in the center of the picture is the Stemwinder tunnel and above it and slightly to the right is seen the dump of the Tyler tunnel. The Stemwinder and Tyler tunnels, once independent mines, are now part of the Bunker Hill and Sullivan. Between the Stemwinder and Tyler, but not visible in Pl. XX, B, are the Last Chance tunnels Nos. 1 and 2, and, lower down, the Sweeny tunnel, one of the principal adits of the Last Chance mine. In the bottom of Milo Canyon, half a mile above Wardner, is the portal of the Reed tunnel, which was the main adit of the Bunker Hill and Sullivan mine before the completion of the long Kellogg tunnel, with its portal near the mill, a mile west of Kellogg. On the west side of the steep ridge separating Milo and Deadwood gulches is the Arizona tunnel, which is a direct continuation of the Sweeny tunnel and belongs to the Last Chance mine. About 100 feet higher up the gulch is the nearly horizontal row of tunnels on the Sierra Nevada vein. On the ridge between Deadwood and Government gulches is the Senator Stewart, a new mine that has recently begun shipping. The principal mines at Silver King, in Government Gulch, are the Silver King on the east side and the Crown Point on the west side. In Grouse Gulch, the next ravine west of Government Gulch, are the Black Hawk and Wyoming mines, which have not yet proved productive.

### HISTORY.

The Bunker Hill lode was discovered in 1885 by N. S. Kellogg and located on September 10 by his partner, Phil. O'Rourke. Their location was shortly followed by the opening of the Sullivan, Stemwinder, Emma, Last Chance, Tyler, and Sierra Nevada mines. The new town on Milo Creek was at first called Kentucky, but this was changed in 1886 to Wardner. Another settlement, a little lower down the creek, originally known as Milo, afterward became Kellogg.

In 1886 ore from the Bunker Hill and Sullivan mines was hauled by wagons over the Mullan road to Mission, thence by boat to the outlet of the lake, where it was transferred to the Northern Pacific Railway for Helena. A narrow-gage railroad, however, was completed from Mission to the mouth of Milo Creek in 1887, and a few months later the Bunker Hill and Sullivan

[a] Officially designated by the company as "the Wardner mine."




GEOLOGIC SKETCH MAP OF THE WARDNER AREA, SHOWING THE RELATIONS OF THE PRINCIPAL ORE BODIES TO THE TOPOGRAPHY AND GEOLOGY

Compiled by F. L. Ransome from Pl. II and mine maps

Scale

0 500 1000 1500 2000 2500 3000 feet

1907

mines were sold to S. G. Reed, of Portland, Oreg. This was the first large mining transfer in the district and the immediate organization of the Bunker Hill and Sullivan Mining and Concentrating Company, with a capital of $3,000,000, gave great impetus to the development of the South Fork mines.

Transportation was badly needed. The Tyler, Emma, and Sierra Nevada mines had tried local smelting at Milo, but this was soon abandoned. The Sierra Nevada about this time was stoping rich carbonate ore assaying 47 per cent of lead and from 60 to 90 ounces of silver, with an average value of $96 per ton. Most of this ore was shipped to Portland, and mining, freight, and treatment amounted to $48.85 a ton. The monthly tonnage produced by the Wardner mines in 1887, according to a contemporary estimate made by Mr. Adam Aulbach, of the "Cœur d'Alene Sun," was as follows:

| | Tons. |
|---|---|
| Bunker Hill and Sullivan | 900 |
| Tyler and Stemwinder | 600 |
| Sierra Nevada | 300 |
| Last Chance | 300 |
| | 2,100 |

It is of interest to note that the daily production (day shift only) of the Bunker Hill and Sullivan mine now exceeds its monthly output in 1887.

In 1890 the completion of the Oregon Railway and Navigation Company's Wallace branch gave the long-awaited facilities for shipping ore and concentrates, and in the following year the Bunker Hill and Sullivan Company built a 500-ton mill on the railroad west of Kellogg, connecting the mill with the workings in Milo Canyon by a tramway.

The labor troubles from 1892 to 1899, which bore heavily on all of the mines, culminated in the destruction of this mill, as already related. The present 1,000-ton plant was soon erected, however, and with the opening of large bodies of ore 2,000 feet below the original discovery, by the Kellogg tunnel completed in November, 1902, the mine has entered on a period of greater prosperity than ever.

The Last Chance mine, which was opened in 1886 by Charles Sweeny and F. R. Moore, of Spokane, was the nucleus of the present Federal Mining and Smelting Company. In May, 1898, the Empire State–Idaho Mining and Development Company was organized to control the Last Chance and to acquire new territory to the west. In 1899 or 1900 the Buffalo Hump Mining Company bought the Tiger-Poorman mine and in 1901 was absorbed by the Empire State–Idaho Company. In September, 1903, the Federal Mining and Smelting Company, organized for the purpose, took over the Empire State holdings, together with the Standard and Mammoth mines.

That litigation should result from the application of the mining laws to such deposits as those at Wardner was inevitable and the long contest between the Last Chance Mining Company and its successors on the one hand and the Bunker Hill and Sullivan Company on the other, with reference to extralateral rights, is a conspicuous example of the intricate operation of these remarkable laws, and the infinite possibilities that they offer to legal ingenuity. The United States circuit court of appeals rendered decisions in favor of the Bunker Hill and Sullivan Company in May, 1904.

## PRODUCTION.

The total output of the Bunker Hill and Sullivan mine to the end of the year 1906, according to figures furnished by General Manager Stanly A. Easton, is 310,663 short tons of lead and 12,659,232 fine ounces of silver. It paid in dividends to the end of 1905 $5,526,000, of which $3,255,000 was disbursed in that year. Additional dividends amounting to $2,346,000 paid in 1906, and $1,260,000 in the first half of 1907 bring the total up to $9,132,000 at the end of July, 1907.

In the fiscal year 1905–6, according to the manager's report, the Bunker Hill and Sullivan mine produced 308,685 tons of concentrating ore, contributed as follows by the different parts of the mine:

| | Tons. |
|---|---|
| Sullivan stopes | 49, 976 |
| Bunker Hill stopes | 255, 428 |
| Stemwinder stopes | 2, 696 |
| Tyler stopes | 585 |
| | 308, 685 |

There was also mined 38,580.58 tons of shipping ore. The average cost of mining, concentrating, and shipping this ore was $1.746 per ton mined.

The average daily run of the concentrator for the year, without allowing for stops, was 846 tons. The total gross value per ton of ore and concentrates as shipped was $52.80 per ton, with the market value of lead 4.255 cents per pound and silver at 63.068 cents an ounce. This total, less freight and treatment charges of $19.90 and operating costs of $6.69, left a profit of $26.21 per ton of shipping product, as against $18.88 in the preceding year.

For the Last Chance mine the available figures are less complete. According to the records of the Federal Mining and Smelting Company, the production up to the end of 1906 (gross metallic contents of ore), has been 106,188 short tons of lead and 4,186,249 ounces of silver.

The Sierrra Nevada mine has been long idle and its total production is not known. The Crown Point has probably produced about $600,000 and the other mines west of Wardner considerably less.

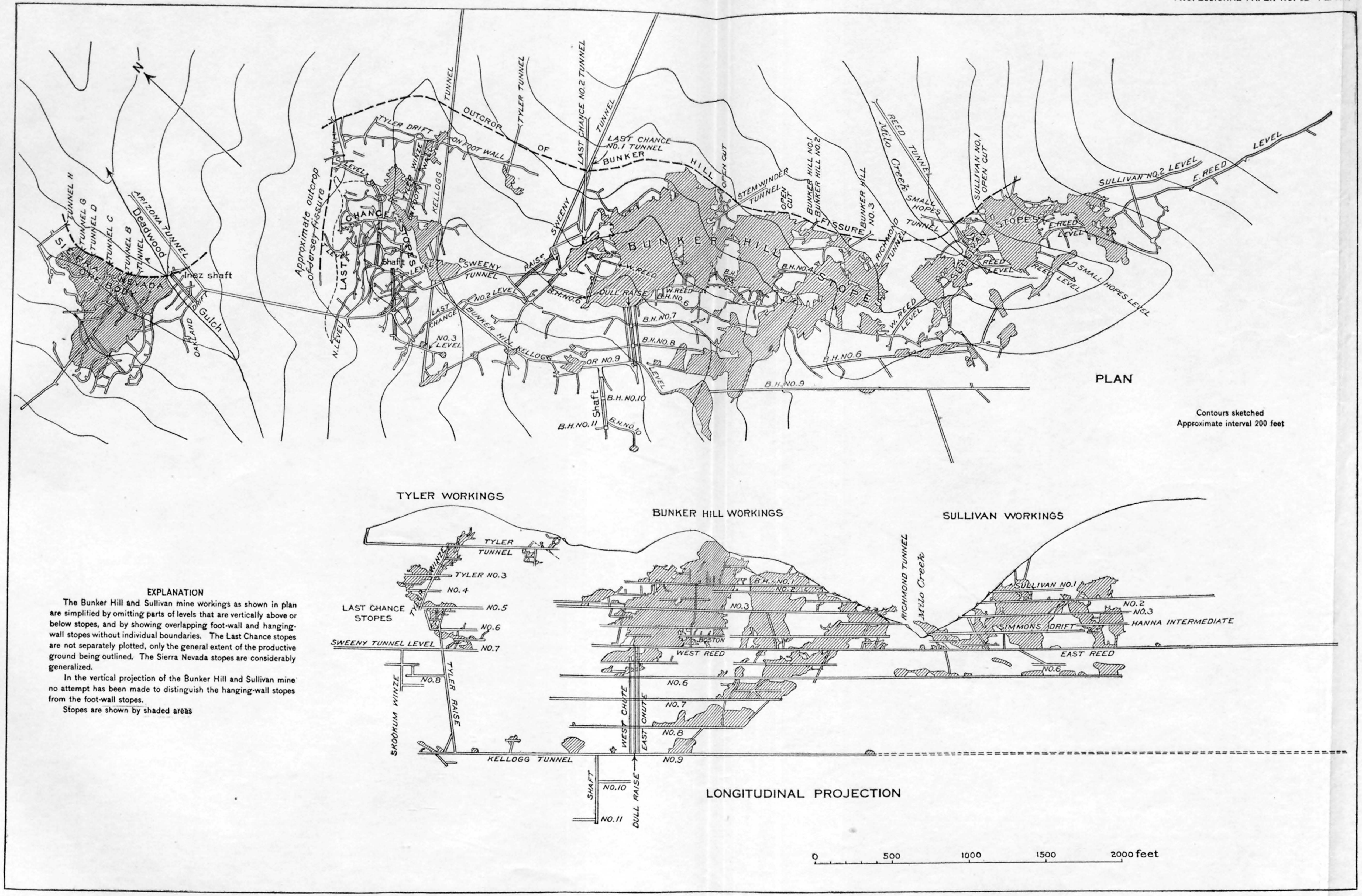
In 1903 the gross value of the product from the principal Wardner mines, according to Mr. Easton, was $3,014,210, or very nearly one-third of the total output of the district. In 1906 the gross value had risen to $6,245,260, while the whole district produced silver-lead ores of the gross value of $16,717,601.

## UNDERGROUND WORKINGS.

The Bunker Hill and Sullivan and Last Chance mines, as shown in Pl. XIX, comprise a very extensive system of underground workings which stretch for over a mile and a half along the northwest-southeast ore-bearing zone. The vertical range of development is approximately 1,900 feet. The lowest level at the time of visit was the Kellogg adit of the Bunker Hill and Sullivan mine. This has its portal 1 mile west of Kellogg at an elevation of nearly 2,350 feet, or only 100 feet above the South Fork of the Cœur d'Alene. This adit, which is not straight, runs in a general south-southwest direction for a distance of 12,000 feet until it cuts the foot-wall fissure of the Bunker Hill lode. The tunnel is 8 by 9 feet in section and is equipped with single-track haulage operated with Spokane electric power. The only work below the Kellogg tunnel in 1904 was an inclined winze which connects with a short drift about 60 feet below the main level (Pl. XIX). During the last three years, however, a shaft has been sunk to a vertical depth of 400 feet below the adit and two new levels run.

Nearly 700 feet above the Kellogg tunnel is the Sweeny tunnel of the Last Chance mine, at an elevation of approximately 3,050 feet. One portal of this tunnel is on the hillside just southwest of Wardner; the other, known as the Arizona tunnel, is in Deadwood Gulch. The Sweeny-Arizona level thus perforates the ridge west of Wardner. It is the principal adit of the Last Chance mine, all the ore being hauled by horses to the Arizona portal and thence carried over a spur of the Oregon Railroad and Navigation Company's line to the mill at the mouth of Government Gulch. Below the Sweeny tunnel is an inclined shaft or winze, 375 feet deep, with three levels.

The Reed tunnel, until the end of 1902 the principal adit of the Bunker Hill and Sullivan mine, is only a few feet above the Sweeny tunnel. Its portal is in the bottom of Milo Canyon, at an elevation of 3,087 feet. The Reed or fifth level is the most extensive in the mine. On the east it penetrates far into the hitherto unproductive country east of the Sullivan ore bodies.




PLAN OF PRINCIPAL UNDERGROUND WORKINGS OF BUNKER HILL AND SULLIVAN, LAST CHANCE, AND SIERRA NEVADA MINES, WITH A LONGITUDINAL VERTICAL PROJECTION OF BUNKER HILL AND SULLIVAN MINE.

From the maps of the companies.

On the west it connects through the Dull raise with levels 6, 7, 8, and 9, the last being the Kellogg tunnel (Pl. XIX). Above the Reed level, on the east side of Milo Canyon, are the Small Hopes tunnel and Sullivan tunnels 3, 2, and 1. On the west side of the canyon are the Richmond tunnel, Bunker Hill tunnels 3, 2, and 1, the Stemwinder tunnel, and some important intermediate levels reached through the Cedar raise (Pl. XIX). The Tyler workings of the Bunker Hill and Sullivan mine lie to the west of the principal Bunker Hill stopes, separated by an interval of comparatively barren ground. They comprise the Tyler tunnel, situated high up on the hillside above Wardner, at an elevation of 3,758 feet. This tunnel connects through the Tyler winze with four levels. The Tyler workings are connected with the Kellogg tunnel by the Tyler raise, and the seventh Tyler level is directly connected with the Sweeny tunnel.

The workings of the Last Chance mine, above the Sweeny tunnel, are reached principally through the No. 9 inclined raise (Pl. XIX). They consist of five main levels, all rather irregular, and connected with extensive stopes on the rich Skookum or Jersey ore bodies, which extend upward into the Tyler ground.

The Sierra Nevada workings are connected with those of the Last Chance mine through what is known as the Oakland drift from the Arizona tunnel. From this drift the Inez inclined shaft (Pl. XIX) extends to the surface and is connected with three levels. The Sierra Nevada lode becomes almost horizontal above the Inez shaft and the upper workings of the old mine consist of a series of tunnels run into the hillside on the west side of Deadwood Gulch. The levels are connected by a labyrinth of abandoned flat stopes and low-angle raises through which it is possible to walk or crawl without ladders.

The Senator Stewart mine in 1904 had been opened by a tunnel 600 feet long and a second tunnel was being driven 250 feet below the existing workings. Nothing that could be identified as the Bunker Hill fissure had been found, although it was thought by those in charge of the development of the mine that the "foot-wall" fissure would be cut in the new tunnel and that the ore of the upper tunnel was in the hanging wall.

The Silver King and Crown Point mines, at Silver King, were only in part accessible at the time of visit. They were being worked on a small scale by lessees. Both are on the same nearly east-west fissure, probably the Osburn fault, which has been explored by tunnels on both sides of Government Gulch. The principal workngs are those of the Crown Point mine, on the west side of the gulch. They comprise two tunnels which penetrate the hill to a maximum distance of nearly 800 feet. From the lower or main tunnel a crosscut extends 500 feet to the south. From the same tunnel an inclined winze was sunk, which followed in general the foot wall of Prichard slate and attained a depth of 600 feet. Three drifts, one of them connecting with the Silver King workings, were run from this winze, but they encountered only a few small bodies of ore.

The Wyoming mine, on the east side of Grouse Gulch, and the Black Hawk mine, on the west side, are both opened by tunnels. The principal work has been expended on the Black Hawk, where over 4,000 feet of drifts and crosscuts have failed to discover ore bodies. No work has been done since 1903.

The O. K. mine, also situated in Government Gulch, about 1,500 feet north of the Crown Point and Silver King mines, was worked through a shaft which was full of water at the time of visit. The ore contains considerable zinc blende and the mine was not profitable. The country rock is Prichard slate.

## GEOLOGICAL RELATIONS.

All of the ore of the Bunker Hill and Sullivan, Last Chance, and Sierra Nevada mines lies in fine-grained sericitic quartzites thought to belong to the Revett formation. The ore bodies are definitely related to a persistent fissure which strikes N. 45° W. and dips to the southwest at an average angle of 38°. Both dip and strike, however, show considerable local variation. This fracture, locally known as the "foot-wall fissure," is in this report called the Bunker Hill fissure. It has been traced almost continuously from the Sullivan claim, on the east side of Milo Creek, to a point about 200 feet down the west slope of the ridge between Wardner and Deadwood Gulch. Southeast and northwest of these respective limits, the Bunker Hill fissure is not definitely known. By some it is thought to be identical with the Sierra Nevada lode; by others to pass through the Senator Stewart, Silver King, and Crown Point claims.

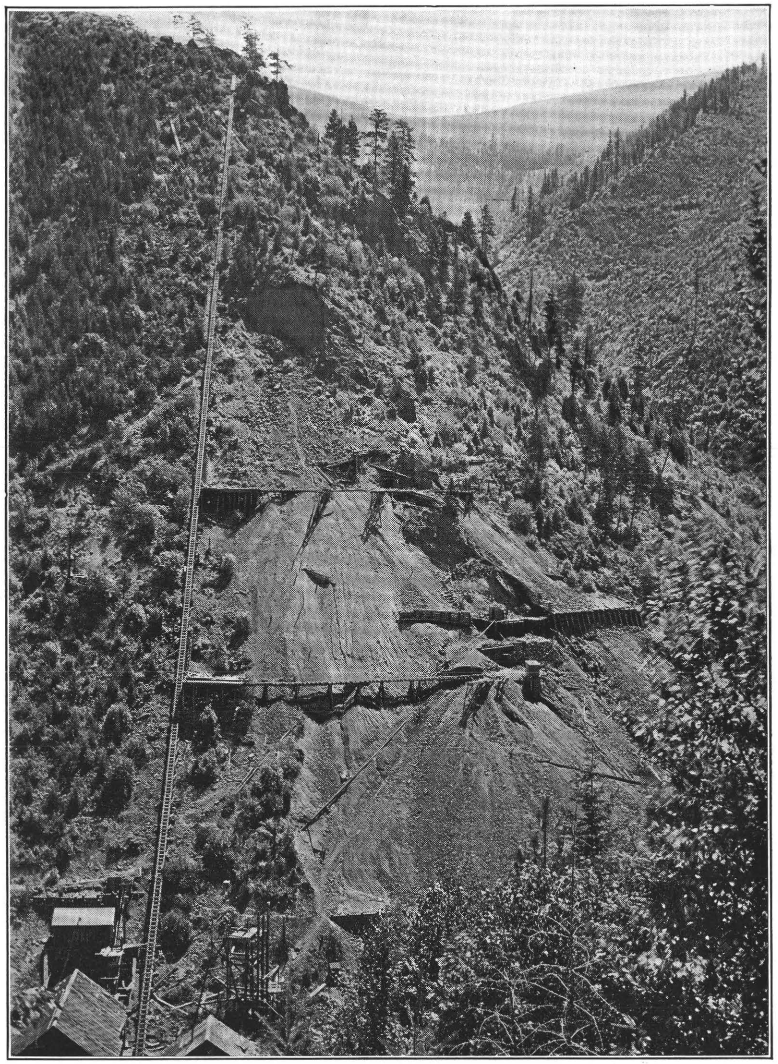
The fissure has all the characteristics of a considerable fault; but the two walls are lithologically identical and whatever faulting has taken place has not perceptibly affected the structural relations of the rocks at the surface. The amount of the displacement along the Bunker Hill fissure and its character, whether normal or reverse, are unknown. By reference to the geological map (Pl. II, in pocket) and to the larger-scale map of Pl. XVIII (p. 154), it may be seen that the Bunker Hill fissure lies on the south side of the great Osburn fault which has been traced by Mr. Calkins from the vicinity of Mullan to the western edge of the area mapped. This is a normal fault with southerly dip. Its course is from N. 75° to 80° W., and it is thus plain that the Bunker Hill fissure and the Osburn fault must come together to the west if each holds its course. Furthermore, as shown in Pl. II, the Osburn fault along most of its course west of Osburn has dropped the Burke and higher formations against the Prichard slate. The Silver King and Crown Point mines, in Government Gulch, and the Black Hawk and Wyoming mines, in Grouse Gulch, are in greatly shattered quartzite, apparently belonging to the Revett formation. This crushed material forms the hanging wall of a southward-dipping fault, with Prichard slate as the foot wall. These mines, moreover, are on a line which coincides, not with the "foot-wall fissure" of the Bunker Hill and Sullivan and Last Chance mines, but with the Osburn fault. It is thus probable that the Bunker Hill fissure, if indeed it crosses Deadwood Gulch, concerning which there is doubt,[a] meets the Osburn fault between Deadwood and Government gulches, somewhere near the Senator Stewart mine, and there terminates. At least it is not likely that the Bunker Hill fissure will ever be recognized in the Prichard slates on the north side of the Osburn fault.

The Kellogg tunnel, which affords the longest and best cross section of the foot-wall country, cuts through the Osburn fault, although as this part of the tunnel is entirely in Burke quartzite which is fissured and disturbed at many places, the exact point at which the fault and tunnel intersect is not precisely determinable. It is probably, however, near the first bend in the tunnel, about 4,000 feet from the portal. As reference to Pls. II and XVIII will show, the Kellogg adit enters in quartzite which has been mapped as Burke, although surface exposures are unsatisfactory and the structural relation of these quartzite beds to the Prichard slates to the west, north, and east of them are by no means well determined. For the first 3,000 feet from the portal the beds show much variation in strike and dip. In general, however, they strike northwest and dip northeast at an angle of 65°. The beds are in many places sharply flexed and are traversed by numerous fissures which are usually filled with a gouge of crushed quartzite. At a distance estimated at 1,500 feet from the portal the tunnel cuts a band of dark slate, possibly 50 feet wide, such as is characteristic of the lower part of the Burke where it grades naturally into the Prichard formation. The presence of this slate suggests that in spite of irregularities of dip the quartzite near the mouth of the tunnel belongs near the base of the Burke formation and rests in generally normal position upon the Prichard.

Near the first bend in the tunnel, or about 4,000 feet from the portal, the quartzite is so badly broken for a distance of several hundred feet that the tunnel required lagging. The Osburn fault probably coincides with this disturbed ground. South of it the beds have a more nearly east-west strike, ranging from N. 50° W. to west, and a general southerly dip of 50° to 80°. These seem to be the prevalent directions of strike and dip of the beds throughout the mines. Near the ore bodies, however, the bedding planes are in many places obscured by sheeting or shattering of the quartzite. Ripple marks serve to distinguish bedding from sheeting, but these are not invariably present. The boundary between the Burke and Revett formations was not recognized in this tunnel.

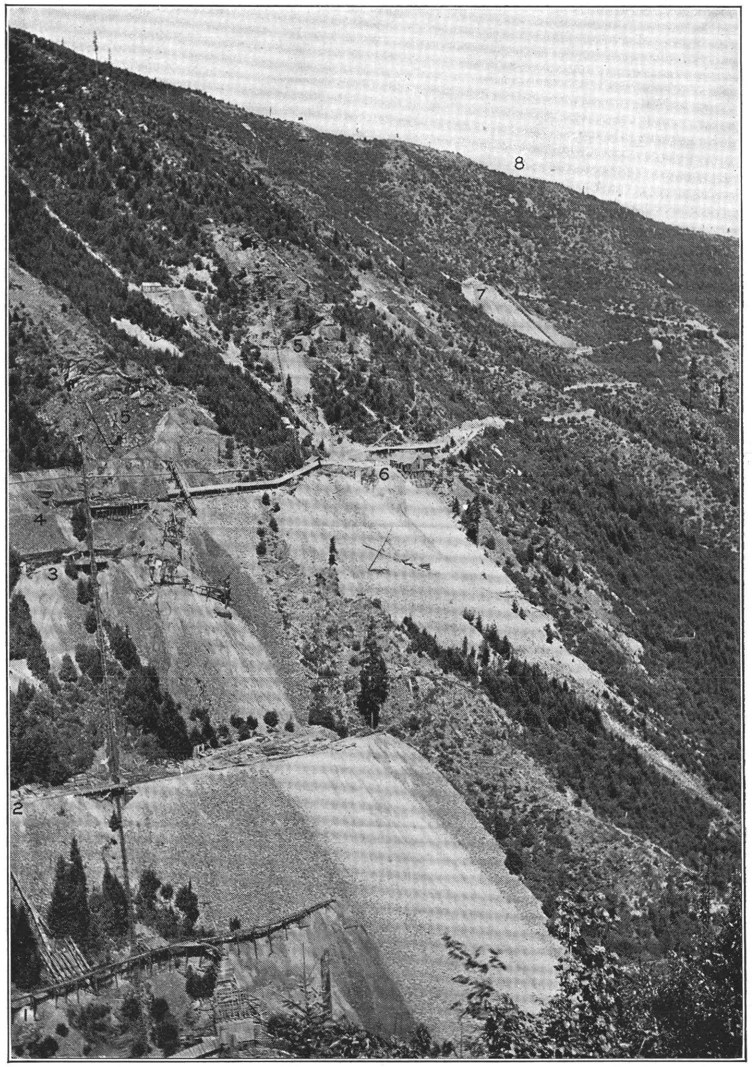
So far as ore deposition is concerned, the Revett quartzite found in the Bunker Hill and Sullivan and Last Chance mines may be regarded as homogeneous material. The formation of

[a] See Finlay, J. R., The mining industry of the Cœur d'Alenes, Idaho: Trans. Am. Inst. Min. Eng., vol. 33, 1903, p. 271, note.



*A.* UPPER TUNNELS OF SULLIVAN MINE, FROM WEST SIDE OF MILO CREEK.

The open cut is seen above the tunnels. East of this cut the Bunker Hill fissure becomes obscure at the surface.




*B.* UPPER WORKINGS OF BUNKER HILL MINE, FROM EAST SIDE OF MILO CREEK.

1, Richmond tunnel; 2, No. 3 tunnel; 3, No. 2 tunnel; 4, No. 1 tunnel; 5, open cuts on Bunker Hill fissure; 6, Stemwinder tunnel; 7, Tyler tunnel; 8, point where fissure crosses the ridge.

the ore bodies appears to have been conditioned by fissuring and the disposition of the ores exhibits no observable relation to bedding planes, nor is there anything to suggest that, within the general zone of mineralization, particular beds have been more favorable than others to the accumulation of ore. Details of folding may thus be eliminated from economic consideration.

The only eruptive rock known in the Bunker Hill and Sullivan and Last Chance mines is a much altered greenstone dike which is exposed at the halfway switch in the Kellogg tunnel. The dike is about 50 feet wide and may have been a diabase or diorite. It is now full of secondary quartz, chlorite, carbonates, serpentine, green amphibole, and other alteration products. The dike is far in the foot-wall country and apparently has no connection with the ore bodies, which are found only in the quartzite of the hanging wall. A similar dike is exposed in the Black Hawk tunnel.

The Bunker Hill fissure is well defined throughout the productive parts of the Bunker Hill and Sullivan and Last Chance mines and is usually recognized with ease by its characteristic appearance. (See Pl. XXI.) There is almost invariably a thin seam (1 or 2 inches) of tough, nearly black clay gouge which usually shows two or more planes of movement and slickensiding. According to Mr. Easton, this gouge contains lead and manganese. Under this seam is a white, creamy, or buff band, ranging from a few inches to a foot or more in thickness, of crushed quartzite which in places is so finely powdered as to form what is usually termed sugar quartz. This white band contrasts strikingly with the black clay seam and this is very characteristic of the Bunker Hill fissure (Pl. XXI). The sugar quartz usually passes gradually into the less disturbed foot-wall quartzite. On the hanging-wall side the black seam is in some places in contact with ore, in others with shattered but barren quartzite.

### FORM AND DISTRIBUTION OF THE ORE BODIES.

Although the quartzite of the foot wall has been well explored, all the ore so far found in the Bunker Hill and Sullivan, Last Chance, and Sierra Nevada mines has lain in the hanging wall of the Bunker Hill fissure. That no ore should have been deposited beneath the persistent seam of dark gouge characteristic of this fissure is remarkable, as the quartzites of the foot wall are identical in character with those of the hanging wall and are in places extensively fissured and broken, though usually less so than in the hanging wall. In the hanging wall, in addition to much irregular fracturing, two sets of fissures may be distinguished, one approximately parallel to the Bunker Hill fissure and the other nearly at right angles to it.

The zone of fissured quartzite in which the ore bodies occur has a maximum width of 300 feet, measured perpendicularly to the Bunker Hill fissure. Within this zone, here in contact with the foot wall, there separated from it by barren quartzite, are numerous irregular ore bodies, usually without definite walls or boundaries. Locally, however, the ore may be bounded on one side by the clay gouge of the Bunker Hill fissure or on one or more sides by some of the subsidiary hanging-wall fissures. The general form and dimensions of the ore bodies are indicated in Pl. XIX (p. 156) and in fig. 12 (p. 126), which is a section across a productive part of the ore zone. It happens, however, that none of the ore bodies, where cut by this particular section, are in contact with the foot wall. It is difficult to convey a satisfactory idea of the dimensions of ore bodies so lacking in regularity. Individual pay shoots may be 500 feet in length, 100 feet or more in width, and 300 or 400 feet in depth. The whole fissured zone, 300 feet in width, may, in a broad sense, be regarded as a single great lode, within which the partly overlapping and partly connected ore bodies are not uniformly distributed in the plane of the zone but are grouped into at least four fairly distinct shoots. The most southeasterly of these is the Sullivan ore shoot, which has been extensively stoped above the Reed level but which is as yet unexplored below the sixth level of the Bunker Hill and Sullivan mine (Pl. XIX), although it will probably soon be reached on the ninth level. On the west side of Milo Creek, extending from the Richmond tunnel up the hillside to the open cut just above the Bunker Hill No. 1 tunnel, is the original Bunker Hill ore shoot, which above the Reed level might perhaps be regarded as two shoots. (See Pl. XIX.) This is apparently the same great ore shoot which is now being stoped on the eighth and ninth levels, and in the new tenth and eleventh levels, below the Kellogg tunnel.

Still higher up the slope a third shoot, which may conveniently be designated the Blacksmith ore shoot, from the name of the first stope, comes to the surface and has been extensively worked down to the sixth level. Below that level very little ore belonging to this shoot has as yet been found.

All three of the foregoing shoots, so far as developed, pitch to the northwest at an angle of approximately 45°. A fourth shoot is cut in the Tyler tunnel, near the crest of the ridge separating Milo Creek from Deadwood Gulch, and seems near the surface to have a northwest pitch, like the others. This shoot, however, which is the one whence the Last Chance mine has obtained the bulk of its ore, lies in the pitching trough formed by the Bunker Hill fissure and the Jersey or Skookum fissure, and the local northwest pitch observable in the Tyler workings is replaced at greater depth by the southeast pitch due to the dip of the Jersey fissure. The

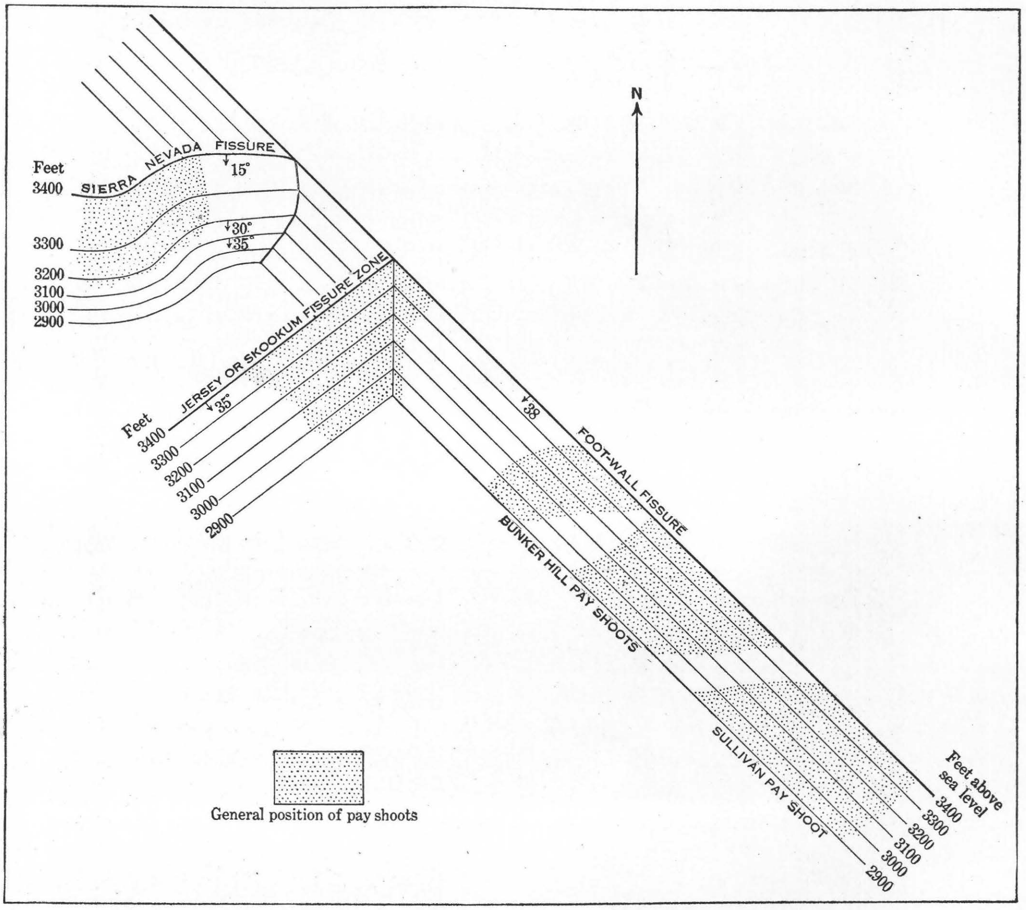


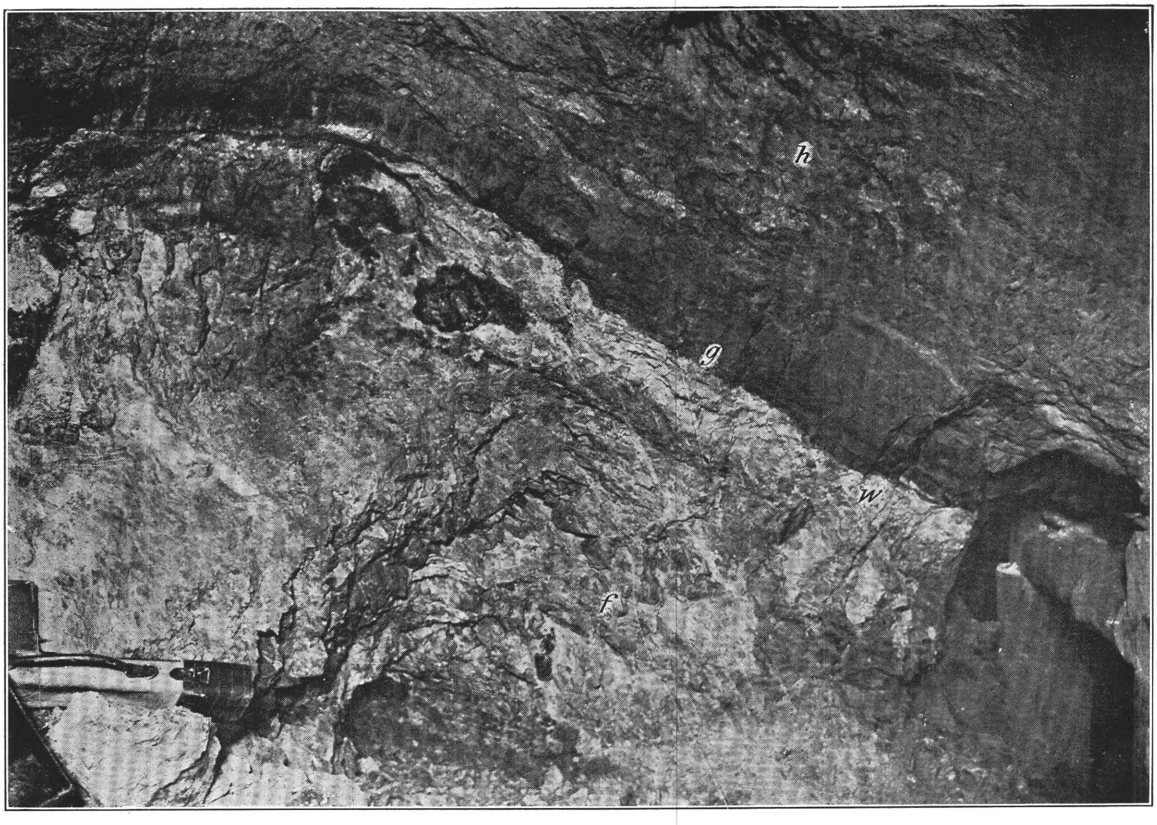

FIG. 18.—Stereogram showing the general relations of the principal fissures and pay shoots of the Wardner group of mines, within a vertical range of 500 feet. The observer is supposed to be looking vertically down upon the lodes, which are represented as opaque sheets ruled with contour lines 100 feet apart. The general positions of the pay shoots are indicated by stippling.

general relation of the Tyler, Jersey, or Skookum ore shoot to the Bunker Hill and Jersey fissures is shown diagrammatically in fig. 18.

The Jersey fissure, or, more correctly, fissure zone, has an approximately northeast-southwest course and thus meets the Bunker Hill fissure nearly at right angles on any given level. It dips to the southeast, apparently at an average angle of 35°; but as it is less regular and has been less continuously explored than the Bunker Hill fissure the average dip has not been accurately determined. The principal fissure of the Jersey zone resembles in general character the Bunker Hill fissure and is related in a similar manner to ore bodies of irregular shape and distribution lying within its hanging wall. Very little ore in the Last Chance mine has been


*A.* OPEN CUT ON BUNKER HILL FISSURE.

*f*, Foot wall; *g*, crushed quartzite and gouge in the fissure, *h*, fissured quartzite of hanging wall.




*B.* BUNKER HILL FISSURE AS EXPOSED IN SECOND LEVEL OF LAST CHANCE MINE.

***h***, Hanging-wall quartzite, here much shattered; ***g***, persistent dark gouge; ***w***, white seam of crushed quartzite that usually underlies the clay gouge; ***f***, foot-wall quartzite.

found along the Bunker Hill fissure except where it is joined by the Jersey fissure zone which so far as known ends at the junction.

Under the Jersey fissure zone, and lying approximately parallel to it, is a second fissure zone known as the Sambo. This is narrower than the Jersey zone and has not been nearly so productive.

The relation of the Sierra Nevada vein to the Bunker Hill fissure is a moot question and is likely to remain so until some exploration is made of the neglected block of ground lying between the Last Chance stopes and the Inez shaft (Pl. XIX). Although the outcrops of the Bunker Hill fissure and of the Sierra Nevada vein (see Pl. XIX) are suggestive of possible identity, yet a comparison of the courses of the two fissures, as shown, for example, by the Tyler tunnel and by the Oakland drift from the Sweeny tunnel, reveals a decided difference in strike. Moreover, while the Bunker Hill fissure is unusually regular in strike and dip, the Sierra Nevada vein ranges in dip from about 40° on the Sweeny level to horizontal in the upper tunnels and the strike, as shown by the Oakland drift and by all the higher levels, shows pronounced curvature which led J. R. Finlay[a] to describe the vein as forming an anticlinal fold. The condition of the mine at the time of visit in 1904 was such that the existence of this anticlinal fold could not be verified. The ore body of the Sierra Nevada was a fairly regular curved sheet, in few places over 6 feet in thickness, and thus having little similarity to the great irregular replacement bodies along the Bunker Hill fissure. It is a metasomatic fissure vein which is to be compared rather with the Canyon Creek type of veins than with the other Wardner deposits. The character of the ore also was different from that of the Bunker Hill and Sullivan and Last Chance mines. On the whole, the probability is that the Sierra Nevada, like the Jersey or Skookum, is a hanging-wall branch or spur from the Bunker Hill fissure.

The ore bodies of the Bunker Hill and Sullivan mine are usually of entirely irregular form and the longest diameter of the body may lie at any angle with the Bunker Hill fissure. The absence of definite limiting walls to the ore is a characteristic although not invariable feature of these large bodies. Masses of nearly solid galena grade outwardly into ore containing larger proportions of gangue and finally into barren country rock. Here and there, however, the ore ends abruptly at a fissure whose walls show evidence of some movement since a part at least of the galena was deposited. Such a fissure, for example, forms a local hanging wall to part of the large March ore body on the Kellogg level. Similar fissures in some places traverse the ore bodies, and the ore forming their walls is usually slickensided. Nowhere, however, are the fissures important faults. Some ore bodies rest directly upon the foot wall of the Bunker Hill fissure and are slickensided, showing that movement along this fissure has continued since the ore was deposited.

The ore bodies of the Last Chance mine, though in many places fully as irregular as in the Bunker Hill and Sullivan, lie chiefly along the Jersey fissure zone and many of them are roughly tabular parallel to that zone.

The Senator Stewart ore body, as opened in 1904, was about 300 feet long. It strikes N. 35° E. and dips at a high angle to the southeast. The ore forms an irregular, elongated, ill-defined mass in much fissured quartzite. It apparently follows a zone of cross fissuring and may be related to the Bunker Hill fissure much as is the Jersey ore shoot. The position of the Bunker Hill fissure, however, is as yet undetermined west of the Last Chance mine. The main ore body apparently does not reach the surface, being cut off a short distance above the main tunnel by some gouge-filled fissures with low angles of dip.

In the Silver King mine a few small bunches of ore have been found in the badly shattered quartzite forming the hanging wall of the Osburn fault. The ore is said not to occur at a less distance than 20 or 30 feet from the slate foot wall. In the Crown Point mine the ore, which has been mostly stoped out, formed an irregular, rolling sheet in the shattered hanging-wall quartzite. In some places it was nearly horizontal, but in general it had a dip of 20° to 30° NE. It thus dipped toward the southward-dipping Osburn fault, ore body and fault coming together near the main tunnel level in a line of junction which in some parts of the workings is 25 feet

[a] Mining industry of the Coeur d'Alenes, Idaho: Trans. Am. Inst. Min. Eng., vol. 33, 1903, pp. 245-247. (See fig. 5, p. 246.)

above and in others a few feet below that level. No ore bodies of importance have ever been found below this junction. The ore is said to have ended abruptly at the slate foot wall and to have shown some slickensiding, probably due to comparatively recent movement along a fault whose major dislocation antedated the period of ore deposition. The ore body is reported to have ranged from 1 to 20 feet in thickness.

## THE ORE.

The mineralogical character of the Bunker Hill and Sullivan ore is simple, galena and siderite constituting probably over 90 per cent of the whole. Associated with these minerals are usually small quantities of quartz, sphalerite, and pyrite. Some tetrahedrite and chalcopyrite are reported from the Sullivan stopes and from the Tyler workings. These minerals, however, are not characteristic of the principal ore bodies of the Bunker Hill and Sullivan mine—such, for example, as the March stope on the ninth level. The best ore from such stopes consists of rather fine-grained masses of galena with subordinate siderite. This grades into ore in which the siderite exceeds the galena, and this into barren quartzite. The ore is principally a replacement of the Revett quartzite, but the replacement is closely connected with fissuring and some of the galena was deposited in open spaces. A typical mass of ore of moderate richness shows a base of matrix of pale-brown siderite traversed by countless reticulating veinlets of galena. In the poorer ore these veinlets are fairly distinct and show only slight metasomatic enlargement of the original cracks. But in the richer ore they coalesce into bunches of solid galena. It is plain that the quartzite was first fissured and replaced by siderite. Subsequently the siderite was shattered and solutions deposited galena in the intersecting fissures and, by metasomatic replacement, in the siderite of their walls. Where the little fissures were particularly numerous and the other conditions for deposition favorable, the siderite has been wholly replaced by galena. But the process was not entirely so simple. Some of the galena is traversed by stringers of siderite and by veinlets of galena of different (usually finer-grained) crystallization from the mass of the ore. Moreover, here and there galena directly replaces the quartzite. It is evident, therefore, that there has been some recurrence of conditions favorable to the deposition of galena and siderite, and probably also of quartz, pyrite, sphalerite, and other metasomatic minerals. In the Bunker Hill stopes quartz and pyrite are usually most conspicuous in the transition zone from ore to country rock.

The ore of the Skookum or Jersey fissure zone, which has afforded the bulk of the output from the Last Chance mine, has certain mineralogical features which usually serve to distinguish it from the typical Bunker Hill ore. Quartz is more abundant and accompanies some of the best ore. Tetrahedrite and chalcopyrite are present in much of the ore, the tetrahedrite being an invariable indication of ore rich in silver. A considerably larger proportion of the Jersey ore has been deposited in open fissures than is the case with the ore bodies more directly connected with the Bunker Hill fissure. Such ore, some of it consisting of nearly pure galena in which are embedded rounded crystals of quartz several inches in length, occurs at many places in irregular branching veins which show little evidence of replacement and constitute the bulk of the deposit. Elsewhere it is associated with sideritic ore that has clearly replaced the quartzite, as in the great Bunker Hill deposits. Some of the quartz crystallized before the galena, but in many places the crystallization of the two minerals seems to have been contemporaneous. Ore showing solid masses of galena, with crystal grains averaging an eighth of an inch in diameter and with included rounded or distorted crystals of translucent quartz, is exceedingly characteristic of the Jersey fissure zone, as may be seen in the Skookum stope above the eighth level of the Tyler winze, in the Eva stope above the Kellogg level, and in the various stopes of the Last Chance mine.

Neither the Bunker Hill and Sullivan nor the Last Chance mine exhibits a well-defined zone of oxidation. Galena, associated with cerusite, limonite, and wire silver, occurs along the outcrop of the Bunker Hill fissure and partly oxidized ore is found as deep as the Sweeny level of the Last Chance mine. The oxidation at this depth, however, is very local and many of the isolated bunches of oxidized ore are in close and irregular contact with unaltered ore. Ore containing pyrite yields first to oxidation. The galena apparently changes directly to carbonate, no anglesite having been seen in the mines.

Beyond the fact that the fine-grained, often schistose galena found near fissures along which movement has occurred since the ore was deposited is usually richer in silver than the rest of the ore, the Wardner deposits present no evidence of secondary sulphide enrichment.

The ore hand picked from the belt conveyors of the Bunker Hill and Sullivan mill carries about 45 per cent of lead and 17 ounces of silver to the ton. Ordinary shipping ore assays about 40 per cent of lead and 14 ounces of silver to the ton. The best ore, as broken in the stopes without sorting, probably contains approximately 25 per cent of lead and 10 ounces of silver. Over 98 per cent of the ore mined is crushed and concentrated.

The ore of the Last Chance mine is probably on the whole richer in silver, the ore bodies of the Jersey fissure zone containing a larger proportion of the precious metal than those occurring along the Bunker Hill fissure.

The Sierra Nevada ore was all partially oxidized and unusually rich in silver, shipments made in 1886, as already mentioned, containing 47 per cent of lead and 60 to 90 ounces of silver per ton.

First-class ore in the Crown Point mine is said to have carried 65 per cent of lead and 80 ounces of silver per ton. The last shipment contained 45 per cent of lead and 56 ounces of silver per ton, and the last concentrates made carried 43 per cent of lead and 42 ounces of silver per ton. Apparently a larger proportion of silver than lead was lost in milling.

# CHAPTER VIII.—DETAILED DESCRIPTIONS OF THE LEAD-SILVER MINES NEAR MULLAN.

## MORNING MINE.

*Situation and surface equipment.*—The Morning mine, formerly owned by Larson & Greenough, but purchased in 1905 by the Federal Mining and Smelting Company, has its principal underground workings about 2 miles north-northwest of Mullan, in the steep ridge separating Mill Creek and Grouse Gulch. The main adit is No. 5 tunnel, on Mill Creek.

The surface improvements connected with the mine, as may be seen from Pl. XXII, are extensive. The portal of No. 5 tunnel is connected with the mill, about half a mile west of Mullan, by a narrow-gage railway with a grade of about 1 in 12. Shay geared locomotives are used and the railway has proved a very economical and efficient means of handling ore, timber, and supplies. The cars carry 25 tons each and the train of 6 or 7 cars makes six round trips a day, bringing down approximately 900 tons of ore.[a] At the mine proper about 275 men are employed, 250 being underground.

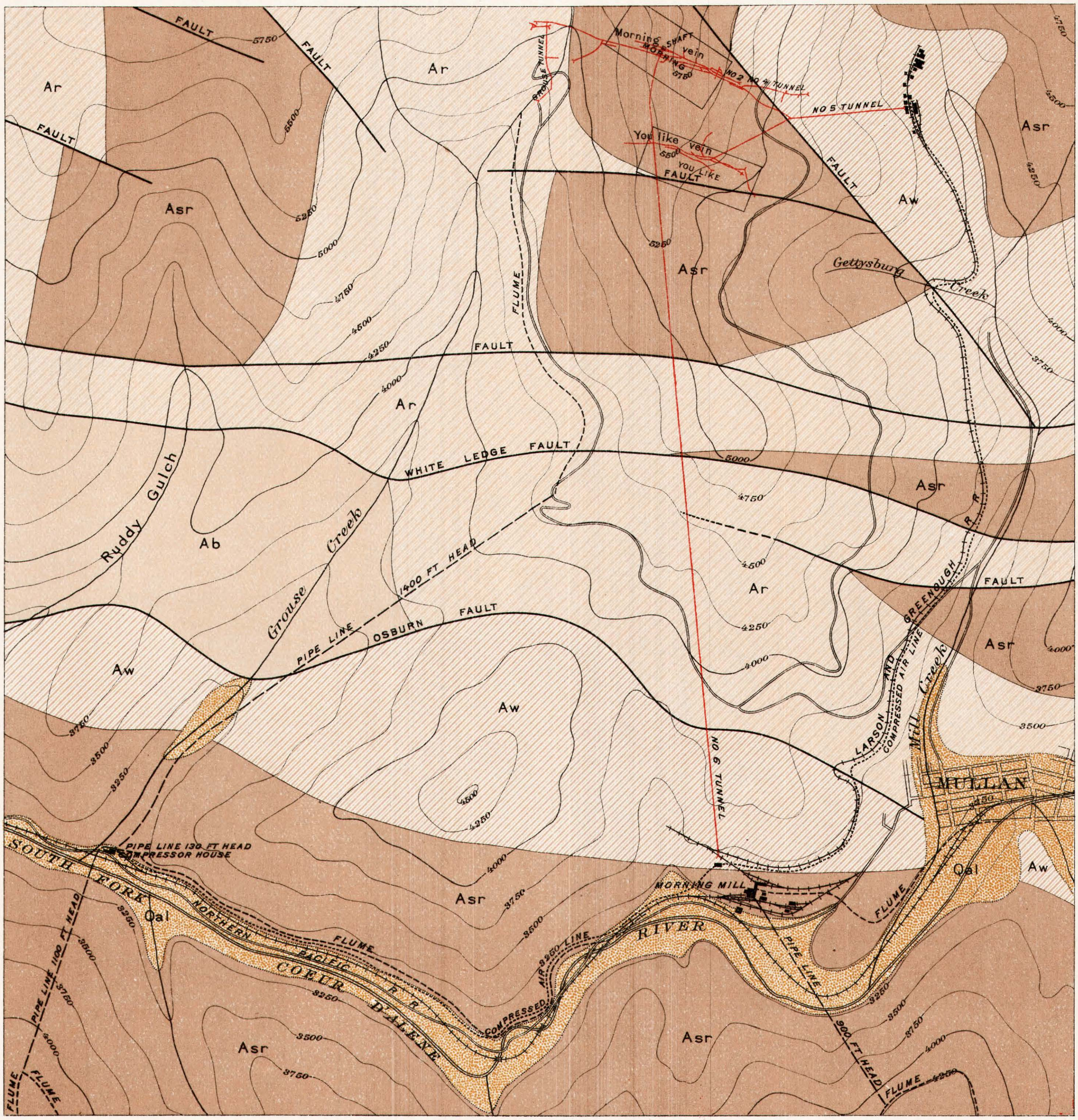
The mill, shown in Pl. XXIV, *A* (p. 168), has a capacity of about 1,000 tons in twenty-four hours. The air compressors are situated at the mouth of Grouse Gulch, about 1½ miles west of the mill. Two 50-drill Rix compressors are run by one 32-foot and two 11-foot Pelton wheels, all attached to the same shaft. The large wheel is run by water from Grouse Gulch under 1,400 feet of head and from Rock and St. Joe creeks under 1,100 feet of head. The smaller wheels are driven by water from South Fork of Coeur d'Alene River under 130 feet of head. In 1904 an independent 40-drill compressor, driven by a 500-horsepower induction motor using Spokane power, was installed to furnish compressed air in times of low water.

As a whole, the equipment of the Morning mine furnishes an excellent illustration of intelligent and extensive utilization of the natural advantages of the district.

*History and production.*—The Morning and You Like lodes were among the first discoveries near Mullan and were originally worked under independent ownership. In 1887 Charles Hussey bought the Morning mine from the locators for $10,000, and two years later he acquired the You Like mine also. He developed the mines extensively, built a mill and wire-rope tramway, and shipped considerable ore, finally selling the property in 1891 for $400,000. The new owners constructed the present railway up Mill Creek and built a 600-ton mill. In 1895 Larson & Greenough bought the Morning mine and secured a lease of the You Like claim, which they subsequently purchased. They made extensive improvements in the plant and by working the Morning and You Like lodes as one mine produced an ore tonnage that in 1904 exceeded that of the Bunker Hill and Sullivan. No. 6 tunnel, designed to deliver the ore directly to the mill, was begun in 1900 and completed in 1906.

No figures for the production of the Morning and You Like mines prior to 1895 are available. The product of the combined mines during Larson & Greenough's ownership is shown in the following table:

[a] Since this description was written the No. 6 tunnel has become the main adit.




Base compiled by F. L. Ransome from Plate II and mine maps

# GEOLOGIC SKETCH MAP SHOWING PLAN OF DEVELOPMENT OF THE MORNING MINE

Geology by F. C. Calkins

0 500 1000 1500 2000 feet

Contour interval 250 feet.
*Datum is mean sea level.*
1907

QUATERNARY

ALGONKIAN

| Qal | Aw | Asr | Ar | Ab | |
|---|---|---|---|---|---|
| Alluvium | Wallace formation | St Regis formation | Revett quartzite | Burke formation | Mine workings |

*Production of the Morning mine, near Mullan, Idaho, 1895–1904.*

| Year. | Lead (pounds). | Silver (fine ounces). | Ounces of silver to each ton of lead. | Year. | Lead (pounds). | Silver (fine ounces). | Ounces of silver to each ton of lead. |
|---|---|---|---|---|---|---|---|
| 1895 | 478,521 | 7,526 | 31 | 1900 | 27,231,899 | 593,429 | 43 |
| 1896 | [a] 7,639,975<br>[a] 6,512,318 | [a] 111,057<br>[a] 204,315 | 44 | 1901 | 24,493,937 | 435,612 | 35 |
| 1897 | [a] 15,528,071<br>[a] 6,817,432 | [a] 303,651<br>[a] 238,696 | 48 | 1902 | 24,792,824 | 474,752 | 38 |
| 1898 | [a] 14,255,423<br>[a] 2,093,943 | [a] 248,354<br>[a] 62,247 | 38 | 1903 | 35 192.482 | 684,914 | 39 |
| 1899 | 13,005,147 | 213,511 | 32 | 1904 | 29,884,078 | 507,353 | 33 |
| | | | | | 207,926,050 | 4,085,417 | 39 |

[a] Upper figures show output from Morning vein; lower figures from You Like vein.

The ore is smelted at Helena, Mont.[a]

In 1905 and 1906 the Morning mine produced 580,390 tons of ore, with a gross content of 57,158,078 pounds of lead and 866,362 ounces of silver.

*Underground development.*—The working adit of the Morning mine in 1904 was No. 5 tunnel (Pl. XXIII), with its portal on Mill Creek, 1⅝ miles north of Mullan, at an elevation of about 4,050 feet. This tunnel is a west crosscut for some 1,500 feet until it cuts the Morning vein. From this point an additional crosscut to the southwest reaches the You Like vein, here about 900 feet from the Morning vein. The four upper tunnels of the Morning mine are no longer used as adits, although No. 4 is still one of the active levels. The vertical distances between levels are shown in Pl. XXII. No. 4 tunnel connects through a raise of 100 feet with the Grouse tunnel with its portal in Grouse Gulch. From No. 5 tunnel a winze or underground shaft gave access in 1904 to a new 200-foot level.

Since the mine was visited No. 6 tunnel, with a portal near the mill, has been completed and connected with the winze from No. 5 tunnel. It has a length of about 11,000 feet and cuts the veins 1,000 feet below the No. 5 level. The intervening ground is as yet only partly explored.

Very little crosscutting is done in the Morning mine, although the structure of the lodes is such as to suggest the possibility of the occurrence of ore to one side or the other of the fissure zones followed by the main drifts.

The You Like vein is worked entirely through No. 5 tunnel, the principal stoping now in progress being from this level and from an intermediate level 300 feet above No. 5. There are three upper tunnels which are no longer used.

*Geological conditions.*—Owing to complex folding and faulting, unsatisfactory exposures, and lack of distinction in the rocks themselves, the geological structure in the vicinity of the Morning mine is somewhat obscure. As shown on the general geological map (Pl. II, in pocket) and on the larger-scale map of Pl. XXII, the west side of Mill Gulch from the mouth of Paymaster Gulch to the terminus of the Larson & Greenough railway is occupied by the green-gray slates of the Wallace formation. No. 5 tunnel enters in these rocks and continues in them nearly to the point of intersection with the Morning vein. Inclosing the Mill Creek area of the Wallace formation on the east, north, and west, and forming the crests of the ridges, is a body of rocks belonging to the St. Regis formation. These of course underlie the Wallace formation and form what is apparently a local syncline pitching to the southeast and bounded in part by faults. Although some of the ore of the old upper levels must have occurred in these St. Regis rocks, they have not been recognized in the stopes now worked, which appear to be entirely within the underlying Revett quartzite. This quartzite, which is the prevalent rock near the head of Grouse Gulch, has evidently been subjected to unusual stresses in the vicinity of the Morning mine and as seen in the mine workings shows an irregular but pronounced slaty cleavage, so that it is distinguishable with difficulty from the rocks of the Wallace formation. The cleavage is most conspicuous in the southeastern part of the mine, the quartzite in the Grouse tunnel having more nearly its usual aspect. The contact of the Wallace rocks exposed in No. 5 tunnel with the

[a] Probably changed under new ownership.

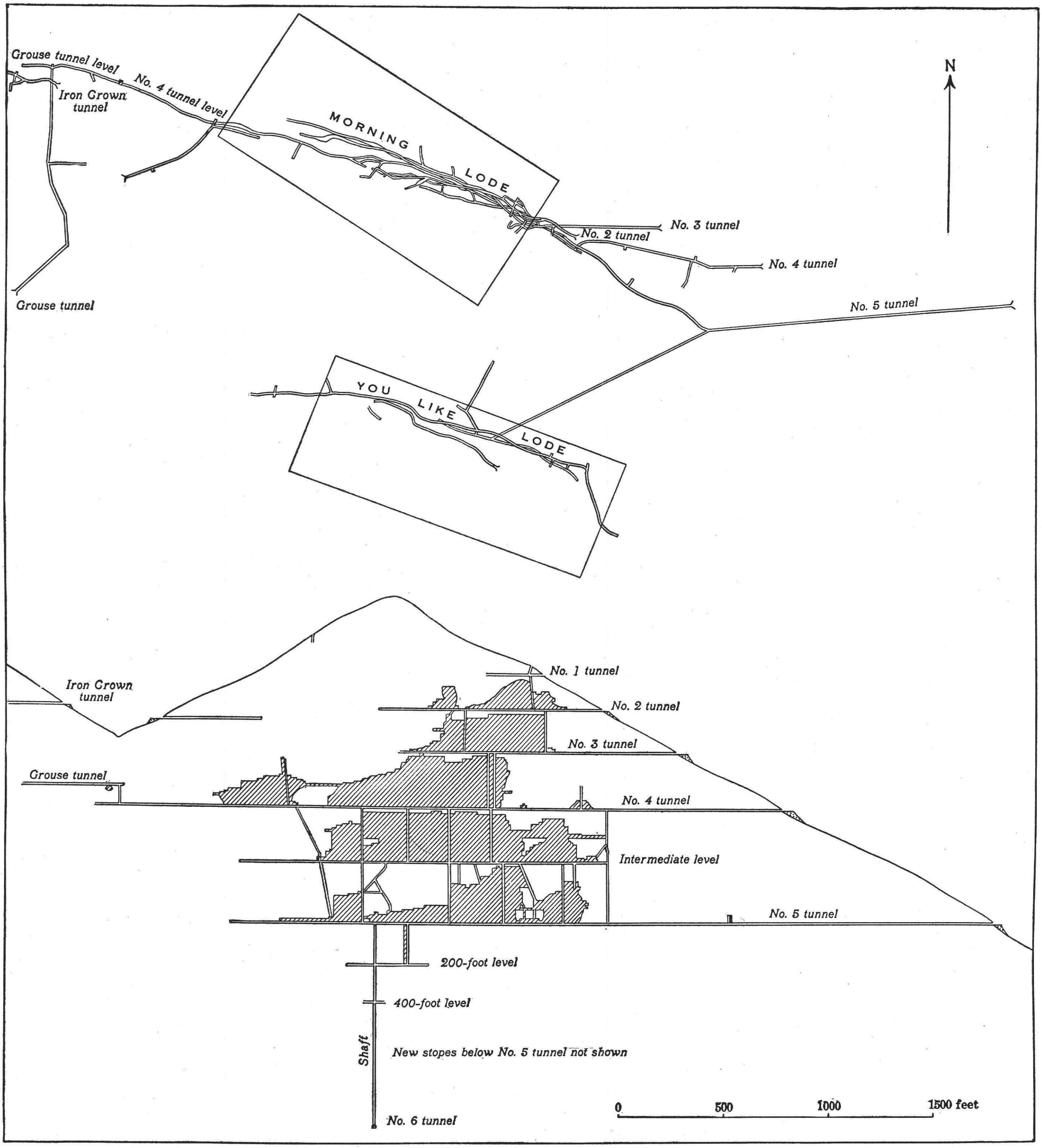
Revett quartzite of the main workings is visible at a point in the tunnel 150 feet east of the Morning vein. At this place the tunnel cuts a dike of a dark decomposed rock ranging from 1 to 2 feet in width. The dike strikes northwest and southeast and apparently dips northeast. It is evident that there has been some fault movement along the dike subsequent to its solidification, but the amount of visible disturbance is slight and the dislocation might easily be disregarded as of little apparent consequence. Close examination shows, however, that this fault and dike mark the line between the more or less calcareous Wallace slates and the noncalcareous sericitic and locally slaty quartzite of the Revett formation. According to Mr. Joseph Carson, superintendent of the mine, a change in the character of the rock was noticed at this point when the tunnel was driven, the rock southwest of the dike being more gritty than the Wallace rocks previously penetrated. He further reported that the same fault was cut in a now abandoned crosscut in one of the upper levels. Here, however, the dike was absent and the fissure was a watercourse, containing much iron oxide. The same fault has been mapped by Mr. Calkins from independent evidence on the surface, extending from the mouth of Paymaster Gulch in a northwest direction over the ridge toward Mace.

On the whole, therefore, the existence of the fault, which is nowhere a conspicuous feature on the ground, seems to be fairly well established. Nothing has been ascertained concerning its relation to the Morning vein, which it should intersect southeast of the point where the vein is cut by No. 5 tunnel. The fissure appears to dip to the northeast and to have a moderate normal throw. As it could be seen at only one point in the mine, however, our knowledge of this fault is plainly far from satisfactory.

As shown in Pls. II and XXII, No. 6 tunnel cuts through the Osburn fault and through a second parallel fault about 3,500 feet farther north. No work was in progress in this tunnel at the time of visit, and the imperfect ventilation allowed only a single hasty examination. About 1,500 feet from its portal the tunnel penetrates a fault breccia, consisting of fragments of quartzite in a clay matrix. The breccia is at least 6 feet wide and seems to dip southward at 70° or 75°. North of the breccia the beds are greatly disturbed and crushed for a distance of fully 500 feet. This is probably the Osburn fault. From this fault to the face of the tunnel the rocks show numerous zones of disturbance, in many places being so shattered as to require close lagging. It is probable that these zones represent subsidiary faults parallel, or nearly so, to the Osburn fault. Throughout the tunnel the rocks are so generally similar that only a most minute examination, under favorable conditions, could distinguish the two or three different formations which are probably there exposed. Most of the tunnel is apparently in the Revett formation. The end of the adit, however, in 1904 was apparently in the St. Regis formation, this rock, according to Mr. Carson, having been entered about 600 feet from the face. The change from the Revett formation to the St. Regis probably marks the position, at the tunnel level, of the fault already referred to as being about 3,500 feet north of the Osburn fault.

The fact that the bulk of the Morning ore is in the Revett quartzite, taken in connection with the relatively high level of the present main adit, is an asset of decided promise as regards the mine's future. In spite of its large production, the mine, as previously pointed out, is yet in a youthful stage of development and there is every reason to suppose that ore bodies which have proved so profitable in the Revett quartzite will be equally so in the underlying Burke formation, which contains the ores of the Canyon Creek mines and which, as shown on page 106, is a formation favorable to the deposition of silver-lead ores. The two formations, it will be remembered, are not sharply separable and it will probably be impossible to determine underground where one is succeeded by the other.

In addition to the small dike already mentioned as exposed in No. 5 tunnel, a decomposed basic dike of unknown width and trend is cut by No. 6 tunnel near its portal. Another dike, composed of a dark-gray aggregate of plagioclase, hornblende, and biotite, is exposed in the Grouse tunnel. The rock is apparently a fine-grained kersantite, but the microscope shows that the feldspars are almost wholly decomposed and that considerable secondary quartz and pyrite are present. The main dike seems to run about north-northwest, but is either very irregular




PLAN OF UNDERGROUND WORKINGS OF MORNING MINE, WITH A LONGITUDINAL VERTICAL PROJECTION OF THE WORKINGS ON THE MORNING LODE.

From the maps of the company.

or is accompanied by smaller dikes of the same rock. None of the dikes in the Morning mine has had any apparent influence on ore deposition.

*Structure of the veins.*—The only veins of importance in the Morning mine are the Morning and You Like. As shown in Pl. XXIII, these are nearly parallel and are 1,000 feet apart. The general strike of the Morning vein is N. 63° W. and of the You Like vein N. 72° W. Both are nearly vertical, the average dip being probably over 85° and to the northeast. In the northwestern part of the workings the dip of the Morning vein decreases to 80°. This vein has been explored for a length of more than 3,000 feet, from the point where it is cut by No. 5 tunnel to the Grouse and Iron Crown tunnels, on the west side of Grouse Gulch. The part of the lode thus far productive is a little less than 2,000 feet in length. The You Like vein has a known length of 1,500 feet, of which about 800 feet has been productive. Whereas in the Morning vein the stopes range from 3 to 40 feet and average 9 feet in width, in the You Like the average is about 6 feet.

In general the two lodes are simple in structure, having few branches and being, so far as exposed, undisturbed by any important faults. At one place, as is well shown by the plan of the No. 4 level, the Morning vein incloses a horse about 800 feet long and 60 feet in maximum width. Both branches of the lode are productive. The You Like vein is crossed at many points and at various angles by small fissures which usually dip toward the east. These are later than the ore, as shown by slickensides, and most of them are unimportant normal faults. Many of them do not perceptibly displace the You Like lode, and the greatest offset observed was 5 feet.

Between the Morning and You Like lodes are a few narrow, undeveloped veins which carry a little ore. It will be noted (Pl. XXIII) that No. 5 tunnel is the only level which crosscuts the rock between the main lodes. It is possible that some of these veins which appear so unpromising where intersected on this level may expand into deposits of workable size farther northwest. The Morning vein itself is a very inconspicuous feature and carries no ore where first cut by this tunnel.

Structurally, the Morning and You Like lodes are metasomatic fissure veins in zones of close sheeting which follow, or cut at small angles, the prevalent slaty cleavage of the quartzite. The fissuring is so close and so intimately related to the general cleavage and fissility of the rocks that parts of the lodes might appropriately be called shear zones. The ore has been deposited along these zones, as the filling of small fissures, as lenticular streaks following cleavage planes, as irregular bunches at intersections of fissures, and as minute reticulated veinlets similar to those of the Bunker Hill and Sullivan mine. Some replacement of the quartzite by ore is everywhere evident and is usually very marked. The ore bodies are without definite walls but pass gradually, by decrease of galena, into the country rock. Many of the stopes show a conspicuous vertical banding due to the deposition of ore along slightly gaping cleavage cracks. Individual bands are not continuous for long distances, but pinch out and are succeeded by others. The formation of the lodes seems never to have resulted in the production of large open fissures but rather in a multitude of narrow fissures, usually less than an inch in width, which enabled the ore-bearing solutions to attack and replace the adjacent quartzite.

The ore of the Morning vein is cut by numerous fissures which are later than the ore. They are structurally unimportant and have had no appreciable enriching effect on the ore in their vicinity. One of these fissures follows the main Morning lode, running on the south side of the horse. Others cut the lode at various angles up to 90°.

The pay shoots of the Morning mine are regular and persistent, that of the Morning vein reaching on No. 4 level a length of at least 1,750 feet. The You Like pay shoot is shorter, the stope length on any one level not exceeding 700 feet. Large as they are, the stopes have not yet reached the stage at which they define the approximate outline of the ore bodies in the plane of the vein. So far as developed, the pay shoots seem to have a vertical pitch and appear to be increasing rather than diminishing in length on the lower levels. Good ore occurs on both sides of the horse in the Morning vein and, according to Mr. Carson, the widest ore in one branch is usually opposite the widest ore in the other.

*Character of the ores.*—The principal ore mineral of both veins is galena, associated with sphalerite, pyrite, and a little pyrrhotite. The gangue minerals, named in the order of their abundance, are siderite, barite, and quartz. Although pyrite and sphalerite are present in all of the ore, they are particularly prominent in the outer parts of the ore bodies and in the zones of transition from ore to country rock. Here and there the ore shows reticulated veinlets of galena in siderite similar to those described in the Bunker Hill and Sullivan mine. The galena is fine grained, much of it a steel-like texture, and scarcely anywhere occurs in such large and pure masses as in the Wardner mines. The different ore minerals are usually aggregated without definite sequence or arrangement, although a banded structure, due to deposition along cleavage planes or parallel fractures, is fairly common.

The ore is generally of low grade, the average for the whole mine ranging from 7 to 9 per cent of lead, and from 3 to 4 ounces of silver to the ton. Ore with 12 or 15 per cent of lead and 5 to 7 ounces of silver is unusually good. The oxidized ore of the upper tunnels of the You Like mine, which consisted in part of plattnerite, cerusite, and native silver, was exceptionally rich, and in the present workings the You Like ore contains nearly twice as much silver to each pound of lead as the Morning ore. In 1904 about one-eighth of the total ore came from the You Like vein. All the ore is concentrated, about 1,000 tons daily being reduced to a little over 120 tons of concentrates.

The ore below the zone of oxidation is said to have shown no change in character with increasing depth. Examination of the table of production on page 165, however, suggests that there may have been some decrease of silver in the ore relative to the lead, although it is impossible to verify this suggestion without a knowledge of the proportion of the ore produced each year by the You Like vein. The ore produced from each vein in 1897 seems to have been richer in silver than that of any suceeding year.

Although considerable rich oxidized ore occurred in No. 1 and No. 2 tunnels of the original You Like mine, the present workings show no oxidation. The Morning vein shows galena at its croppings on the hillside south of the portal of No. 4 tunnel. It is said that in both veins very little oxidized ore occurred below a depth of 200 feet. Although the mine is generally wet, the water all percolates down from the surface and the mine is apparently still (1904) above the level of general ground water.

## GOLD HUNTER MINE.

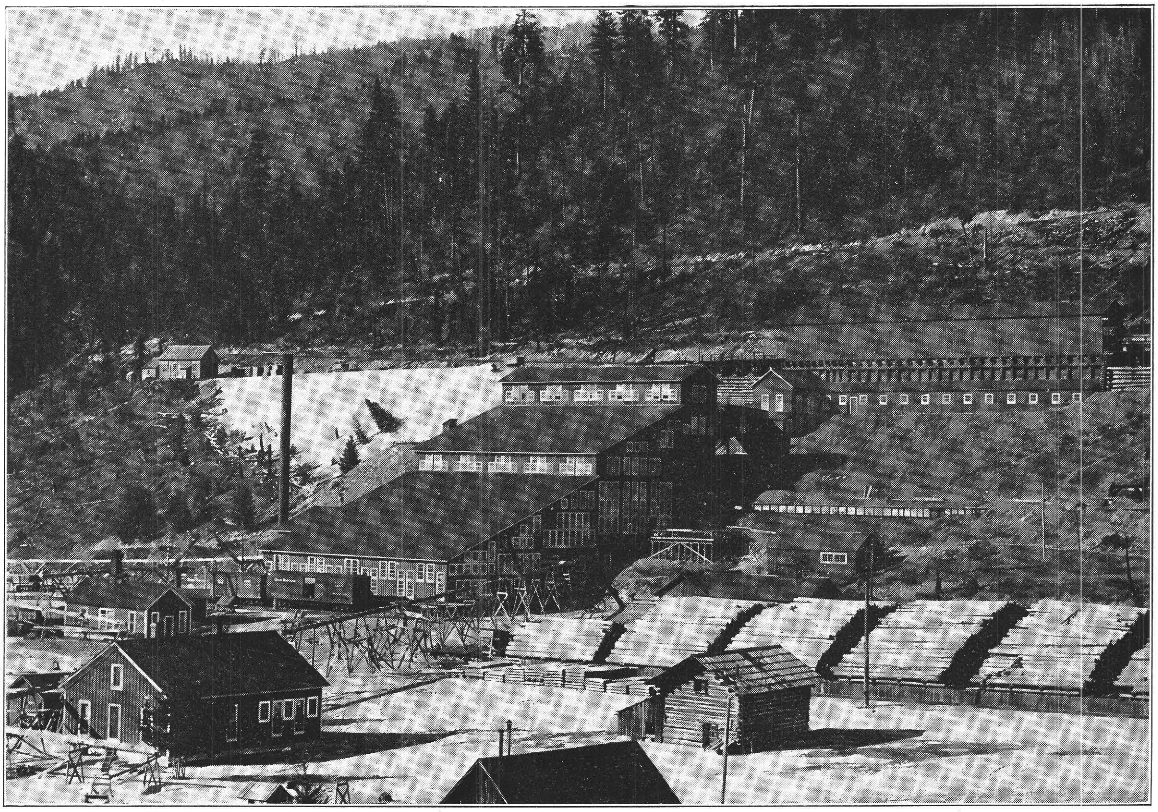
*Introduction.*—The Gold Hunter mine, owned by the Gold Hunter Mining and Smelting Company, is situated in Hunter Gulch, a mile northeast of Mullan. The lode, which is in the general line of continuation of the Morning and You Like veins, was discovered early in 1884 by Messrs. Hunter and Moore and soon became noted for its rich argentiferous ore, which, according to the "Coeur d'Alene Sun" of December 3, 1885, carried as much as 400 ounces of silver. The rich ore near the surface changed in depth to the generally low-grade ore of the present workings. The mine of late has been neither a profitable nor a steady producer. At the time of visit from 150 to 160 tons of ore were mined daily.

The production of the Gold Hunter mine is shown in the following table:

*Production of the Gold Hunter mine, near Mullan, Idaho, 1902–1906.*

| Year. | Ore mined (tons of 2,000 pounds). | Silver (fine ounces). | Lead (pounds). |
|---|---|---|---|
| 1902 | 34,871 | 162,528 | 2,731,092 |
| 1903 | 34,331 | 145,262 | 2,795,746 |
| 1904 [a] | 11,760 | 39,200 | 705,469 |
| 1905 | 31,930 | 106,500 | 1,917,213 |
| 1906 | 47,357 | 152,985 | 1,414,122 |
| | 160,249 | 606,475 | 9,563,642 |

[a] Mine operated for part of year only.



*A.* MILL OF MORNING MINE.

The dump of the No. 6 tunnel is visible to the left. Photograph by T. N. Barnard.

*B.* TOWN OF BURKE, FROM THE WEST.

On the right is the shaft of the Hecla mine. Farther back, to the left, are the shaft and mill of the Tiger-Poorman mine. Photograph by T. N. Barnard.

*Underground development.*—The principal adit of the Gold Hunter mine is No. 5 tunnel (fig. 19), with its portal in the bottom of Hunter Gulch, at an elevation of about 3,900 feet. This is by far the most extensive level in the mine. Above it are four older tunnels, which are no longer used, and below it two levels, at intervals of 100 feet, which are reached by a winze from No. 5. From the portal of the main adit the ore is carried to the mill at the mouth of Hunter Gulch by a wire-rope tramway 4,000 feet in length.

*Geological conditions.*—The rock of the accessible workings of the Gold Hunter mine is uniformly a pale greenish-gray sericitic slate, much of which has a waxy appearance. This slate has a close resemblance to the rocks typical of the Wallace formation, but the geological structure of the vicinity as worked out by Mr. Calkins indicates that it probably belongs to the St. Regis formation. Both formations contain rocks that are identical in lithological character, and this fact, added to the poor exposures and the generally obscure geological structure near Mullan, leave the reference of the country rock of the Gold Hunter mine to the St. Regis open to some question. The essential and determined facts, from an economic standpoint, are that the ore occurs at a higher stratigraphic horizon than in the Morning mine and that the

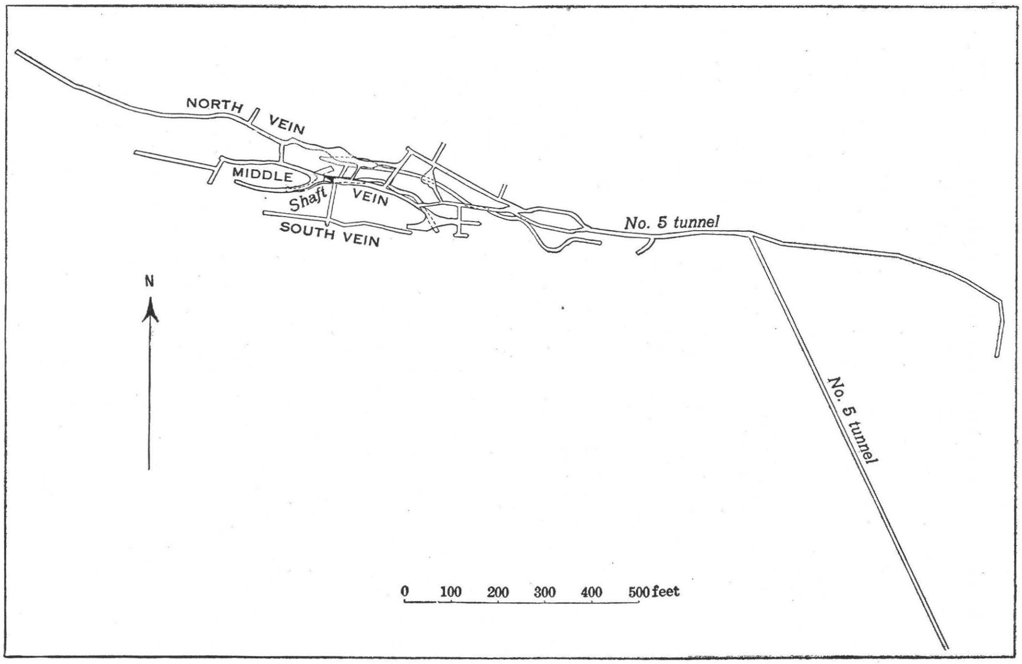



FIG. 19.—Plan of part of the underground workings of the Gold Hunter mine.

country rock, from No. 5 tunnel to the 200-foot level, is all of one type although varying in perfection of cleavage. Surface relations, as shown in Pl. II (in pocket), indicate that the richer ore of the upper tunnels, like the ore of the Morning mine, occurred in the Revett quartzite.

The country rock shows no bedding and generally has a well-developed, nearly vertical cleavage. In many places stresses have changed cleavage planes into visible partings, so that the rock is strictly fissile as well as cleavable. The cleavage faces are less regular than in roofing slate, but are unctuously smooth and have a waxy luster. Although the term slate conveys the truest impression of the appearance of the rock, it is in reality a very fine-grained sericite schist, composed essentially of quartz and sericite. The prevalent parallelism of the mica scales gives the rock its cleavability and to the same mineral is due the faint greenish tint and waxy luster of the cleavage surfaces.

*Arrangement and structure of the veins.*—In general the veins of the Gold Hunter are parts of a zone of fissuring and shearing at least 70 feet wide. The strike of the zone is from N. 75° to 80° W., and its dip 80° or more to the south, it being approximately parallel to the cleavage of the country rock. As may be seen from fig. 19, the principal development has been on three veins, known as the north, middle, and south veins. All are practically vertical. These veins show several branches, in some places inclosing horses, as shown on the fifth tunnel level in fig. 19. Between the main veins are less important streaks of ore, some of which have been stoped. The lodes are essentially zones of shearing and fracturing along the general cleavage planes of the rock and individually are not very persistent. Locally they cut the cleavage at small angles. At the ends of the ore shoots the lodes are usually indistinct and they can rarely be followed far before they are lost in the general fissility of the slaty country rock. The productive part of the entire zone is from 900 to 1,000 feet in length, but continuous stopes are not over 250 feet long, the occurrence of the ore being comparatively bunchy. The maximum stope width is 25 feet. The principal output has come from the north vein.

In the formation of the Gold Hunter veins no wide openings were produced. Strong stresses transformed cleavage into fissility and produced some shearing along a zone which thus afforded passage to ore-bearing solutions. The ore has been deposited chiefly by metasomatic replacement of the quartz-sericite slate or schist.

*Character of the ore.*—The minerals known to be present in the Gold Hunter ore are galena, sphalerite, pyrite, tetrahedrite, stibnite, siderite, barite, and quartz. These are rather unevenly distributed. Tetrahedrite does not in general occur in visible masses in the present workings, but was much more abundant in the upper tunnels. In 1904 lessees, working close to the surface above the old No. 1 tunnel, were taking out ore said to contain as much as 140 ounces of silver and 53 per cent of lead. This ore, which occurred as residual masses in cerusite, consisted of galena and tetrahedrite in a gangue of quartz and barite. The dumps of tunnels Nos. 2, 3, and 4 all show some tetrahedrite, indicating that the ore formerly extracted from these workings was richer than that now mined.[a]

The best ore stoped by the company in 1904 is in the north vein, just above No. 5 tunnel. It is strikingly banded, and consists of thin alternating sheets of fine-grained galena and barite. With the galena is associated a little sphalerite, pyrite, and probably tetrahedrite. The bands are generally parallel to the vein and are probably due to selective replacement of the slaty country rock.

In general the ore now sent to the mill contains much less galena and more pyrite than the Morning ore, these disadvantages being only partly offset by a higher proportion of silver. It averages about 6 per cent of lead and 7 to 8 ounces of silver per ton. The silver, however, occasionally rises to 50 or 60 ounces to the ton. Approximately 12 tons of ore are required to make a ton of concentrates, and concentration is rendered difficult by the presence of barite. Stibnite, while not a common constituent of the ore, occurs at a few places as slender crystals in quartz.

The ore of the south vein is usually more pyritic than that from other parts of the mine, and some of it contains streaks of compact, pitchlike sphalerite with conchoidal fracture.

## PROSPECTS.

*Enterprise.*—The Enterprise prospect lies just east of the Gold Hunter mine and is supposed to be on the same lode. There is a crosscut tunnel connecting with several hundred feet of drifts which for the most part follow the cleavage of the St. Regis slates. A few small stringers of quartz and siderite occur between the leaves or laminæ of the slate, and these contain specks of galena and a little pyrite. A little stibnite was also noted in some small, nearly horizontal stringers of quartz. There is no ore and the Gold Hunter lode probably dies out in the cleavage of the rocks east of Hunter Gulch.

*Alice.*—The Alice property is situated in Ruddy Gulch, 2½ miles west of Mullan, and derives its general interest mainly from its relation to the Osburn fault. A tunnel has been driven northward for 420 feet through sharply folded, thin-bedded Wallace rocks to the lode, which is in Burke quartzite. About 350 feet from the portal the tunnel cuts through the

[a] Since this was written, the Gold Hunter lode has been cut 500 feet below the old workings by a tunnel 4,400 feet in length. Some very good shipping ore, carrying tetrahedrite, is said to have been found on this new level.

Osburn fault here marked by 1 to 2 feet of soft dark clay gouge accompanied by much shattered quartzite. In fact, the Burke beds are broken or shattered for at least 150 feet from the gouge.

Small bunches of galena occur irregularly distributed through this disturbed quartzite along a zone approximately parallel to the fault. At one point some of this ore is fully 400 feet north of the clay gouge. Although the croppings have furnished some excellent ore and have the appearance of a fairly distinct east-west lode, the underground workings have not yet opened any continuous lode or ore body. There seems to have been a zone of east-west fissuring and mineralization in the quartzite which has been disrupted and shattered by later movement along the Osburn fault.

The ore consists of galena and quartz, with some tetrahedrite. Where the latter is abundant, the ore is rich in silver, carrying up to 300 ounces to the ton. Some of the oxidized material at the surface is said to contain some gold.

*Mineral Farm.*—The Mineral Farm prospect, which is also on the Osburn fault, has a tunnel several hundred feet long on the east side of Grouse Gulch, west of Mullan. The tunnel is entirely in the soft crushed material of the fault, which has to be held up by timbering and logging. No evidence of mineralization could be seen at the time of visit.

*Bitter Root.*—The Bitter Root prospect is on Boulder Creek, a little over a mile south of Mullan, on a west-northwest lode. The country rock belongs in the St. Regis formation. The vein is apparently large and of rather varying width, but is not well exposed in the prospecting tunnel. It consists of siderite which is cut by irregular stringers of white quartz. This siderite weathers superficially to limonite, the quartz stringers remaining as a skeleton for the softer alteration product. The dump of the tunnel shows a little pyromorphite but no ore.

The Central, a prospect on the same lode, east of Boulder Creek, was not visited.

*Little Giant.*—The Little Giant prospect is also on the same lode as the Bitter Root and lies about half a mile east of Boulder Creek. There are two tunnels on opposite sides of a ridge and about a third of a mile apart. These are not connected. In the western tunnel, on a tributary to Boulder Creek known as Silver Creek, the lode has a width of over 100 feet. The siderite is all partly oxidized to limonite and the clefts in limonite and country rock are in many places lined with druses of pyromorphite. Within this great lode, which appears to be generally barren, is a vein of barite and galena, not over 6 inches in width.

*Alma.*—The Alma tunnel, on the west side of Deadman Gulch, a mile above its mouth, was about 1,000 feet in length in 1904 and was still being driven. It follows a slip or slight fault parallel to the cleavage of the slaty country rock, which probably belongs to the Wallace formation. This cleavage strikes N. 75° W. and dips 70° S. There was no sign of mineralization in the tunnel at the time of visit.

*Other prospects.*—There are many other tunnels in the vicinity of Mullan, some of them as promising from a commercial standpoint as the two just mentioned. Their description, however, would add nothing of interest or importance as regards the general occurrence of the ores in the district.

## CHAPTER IX.—DETAILED DESCRIPTIONS OF THE LEAD-SILVER MINES ON CANYON CREEK.

### INTRODUCTION.

The important mines of the Canyon Creek group are distributed along that stream from Burke to Gem, a distance of 3 to 4 miles. They include the Tiger-Poorman, or "Burke mines" of the Federal Company, the Hecla, the Hercules, the Standard-Mammoth, or "Mace mines" of the Federal Company, and the Helena-Frisco. All except the last are active producers.

### TIGER-POORMAN MINE.

*Introduction.*—The Tiger mine, situated in the town of Burke (Pl. XXIV, *B*), was the first silver-lead mine opened in the district. The lode was discovered in 1884 by Messrs. Carton and Seymour, who bonded it to John M. Burke. The property was soon after acquired by S. S. Glidden and others for the sum of $35,000, Burke and Carton retaining contingent interests. By the end of 1885 three tunnels had been driven and 3,000 tons of ore were piled up and awaiting shipping facilities. The mine was at first reached from Murray over a trail that became almost impassable in winter; but Colonel Wallace soon opened up a trail to the mine from his store at Placer Center.

In 1886 the Tiger became involved in litigation with the adjoining Poorman mine. This was compromised, and in the following year the Poorman mine, then in unusually rich ore, was sold to Daly, Kingsbury & Clark, of Butte, for $136,000. Both mines already showed great promise and the Tiger was at this time the leading producer of the Cœur d'Alenes. In December, 1887, the narrow-gage railroad reached Burke and in the following year both mines were equipped with concentrating mills. The Poorman mill, with a daily capacity of 150 tons, was then the largest in the district.

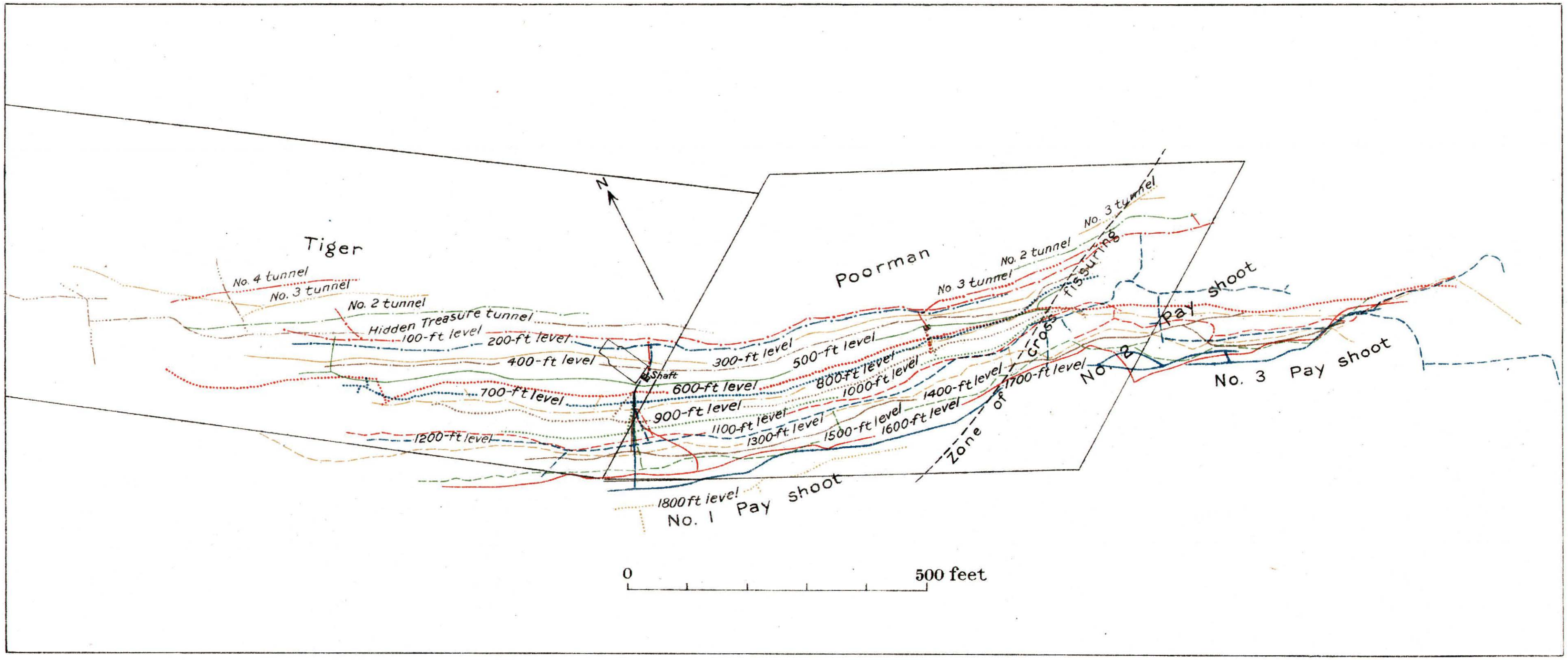
In 1895 the Tiger and Poorman mines were consolidated. In June, 1897, the Tiger shaft had reached a depth of 1,200 feet and the present mill had been completed.

Early in 1900 the Buffalo Hump Mining Company bought the Tiger-Poorman mine and in 1903, as previously related, the property passed into the group of mines owned by the Federal Mining and Smelting Company.

The Tiger-Poorman mine is equipped with a 20 by 60 inch steam hoist of the Corliss type, using flat cables and capable of working to a depth of 2,500 feet. The water entering the mine, about 500 gallons per minute at the time of visit, is raised in one lift from the 1,600-foot level to the surface, by a double Nordberg pump, one half of the pump being held in reserve. This pump is electrically driven as long as water is available in Lower Glidden Lake, but steam is substituted when the water fails.

*Production.*—The gross production of the mine to the end of 1905, as given by the Federal Company, is 811,794 tons of ore mined, with a gross metallic content of 89,199,398 pounds of lead and 286,424 ounces of silver. In 1906 the production of the Tiger-Poorman was not separately reported. It is not known with what year the record begins. The mine was credited in August, 1903, with dividends amounting to $1,763,000. From 350 to 360 tons of ore were hoisted daily in 1904.

*Underground development.*—The principal workings are the Tiger shaft, 1,950 feet deep, with 18 levels. The shaft is situated within the town of Burke, near the east end of the Tiger claim. The old Poorman shaft, about 475 feet farther east, is no longer used. The Hidden Treasure tunnel (Pl. XXV), with its portal near the collar of the Tiger shaft, was about 3,500 feet in




Compiled by F. L. Ransome from the mine maps. The boundaries of the claims may be only approximately accurate.

PLAN OF PART OF THE UNDERGROUND WORKINGS OF THE TIGER-POORMAN MINE

length at the time of visit. It follows a fissure supposed to be the Tiger vein to a point under the abandoned tunnels of the Union mine on the south slope of Tiger Peak. It is thus by far the longest drift in the Tiger-Poorman mine and extends farthest northwest. The other tunnels shown in Pl. XXV are the original workings of the Tiger and Poorman mines and are no longer used. The levels connected with the Tiger shaft are at rather irregular vertical intervals, ranging from 80 to 200 feet. The most extensive of the deeper levels is the 1,200-foot, which has been carried southeastward beyond O'Neil Gulch. The total length of ground explored along the general line of the Tiger lode is over a mile. The ore, however, is restricted to a section, approximately 2,000 feet in length, in the vicinity of the Tiger and Poorman shafts.

Most of the stoping is now being done between the 1,600- and 1,800-foot levels, and in the southeastern part of the mine between the 600- and 1,200-foot levels. The levels above the 800-foot are for the most part stoped out and abandoned.

*Geological relations.*—All of the ore of the Tiger-Poorman mine occurs, so far as known, in the Burke formation. The sericitic and sideritic quartzites are fairly massive and are distinctly bedded. Their strike is usually a few degrees east of north and their dip is to the east at an average angle of 65°. The extreme southeastern part of the 1,200-foot level, however, is in dark slate which in all probability belongs to the Prichard formation. There are lithological indications that the 1,800-foot level is near the bottom of the Burke formation, and the slates of the 1,200-foot level apparently owe their position to an upthrusting of this underlying formation by the prominent fault shown on Pl. II (in pocket) as coinciding with Gorge and O'Neil gulches. The occurrence of the banded transition rocks exposed along the roadside between Burke and Gem and mapped as Prichard by Mr. Calkins is further suggestive of the probability that the Tiger shaft has nearly reached the bottom of the Burke formation.

*Structure of the lode.*—West of the Poorman shaft, the productive part of the Tiger lode, as shown in Pl. XXV, is a gently curved but fairly regular fissure zone with a general strike of N. 60° W. and a dip to the southwest of approximately 80°. It cuts across the bedding of the quartzite, which apparently it has only slightly faulted. East of the Poorman shaft a deflection to the northeast is noticeable on nearly all the levels, apparently due to a cross fissure having the general course indicated in Pl. XXV. East of this deflection the ore occurs in a series of overlapping or imbricated, nearly vertical fissure zones whose approximate positions and directions are shown in the plate. Three of these are usually recognizable and are known as the No. 2, No. 3, and No. 4 ore shoots. Each successive shoot is usually found by crosscutting to the right when the ore in the shoot worked shows signs of pinching, the crosscut in many cases following a linking fissure. On some levels, however, branches from one ore shoot extend obliquely to the other and no crosscutting is necessary. In such places there may even be no distinction between the shoots, the ore curving without break from one to the other. The best marked of these shoots is the No. 3, which is well shown by the superposition of the levels in the Ella claim and in the northern part of the O'Neil claim, as may be seen in Pl. XXV. On the 800- and 1,200-foot levels the ore comes to an end at the fault already mentioned as bringing up the Prichard slate. The fault strikes nearly north and south and dips to the east at an angle of 75°. It is marked by a zone of sheared and crushed quartzite, in places several feet wide and containing one or more seams of plastic gouge. The ore ends against the first gouge seam and is slickensided. It is quite possible, however, that this slickensiding is due to continued movement along a fissure which was already in existence when the ore was deposited.

At the time of visit there was practically no opportunity of making a satisfactory study of the conditions under which the main or No. 1 ore shoot ends to the northwest. It is evident from the mine maps that the northwest limit of the ore pitches southeastward, so that the portion of the ore shoot west of the Tiger shaft becomes shorter on each lower level. At the bottom of the mine there is no ore known west of the main crosscuts from the shaft to the vein. So little is ore expected in this direction that the upper drifts are mostly abandoned and the lower drifts are confined to the country east of the shaft. The No. 3 tunnel and the 600- and 1,300-foot levels all show a significant deflection at their western ends, which is probably due to the existence of a cross fissure. West of this fissure no ore in paying quantities has yet been found in the Tiger-Poorman mine.

The internal structure of the Tiger vein is that of a metasomatic stringer lode, in which, however, replacement is less prominent than in the Wardner and Mullan mines. The lode cuts across the beds, which usually retain their distinct stratification and are not so generally slaty or schistose as in the Mullan mines. The ore shows very little tendency to extend out along bedding planes. Well-defined filled fissures or stringers are common in the Tiger lode, many of them carrying a gangue of white quartz. These stringers of quartz are not all of the same age; some of them cut the ore, while others are cut by veinlets of galena.

That the formation of the lode was accompanied by shearing is shown by the development of local cleavage or schistocity in the quartzites alongside of and parallel to the lode. As in most of the Cœur d'Alene lodes, real walls are lacking, owing to the irregular replacement of the fissured rocks by ore. There has been some movement along the vein, however, since the ore was deposited and these later fissures or slips in some places constitute local walls. The stopes range from 4 to 15 feet in width.

*The ore.*—The ore consists of galena associated with pyrite, pyrrhotite, chalcopyrite, and sphalerite, in a gangue of quartz and siderite. It is prevailingly of low grade, averaging a little less than 6 per cent of lead and 3 ounces of silver per ton. The best ore is said to have occurred above the 600-foot level and it is certain that pyrite, pyrrhotite, and sphalerite are more abundant on the 1,800-foot level than anywhere else in the mine. Tetrahedrite was not recognized in the ore, but is probably not entirely absent. The various ore minerals seem to belong to one general period of crystallization and exhibit no regular sequence. All of the ore is milled, about 9 tons of ore making 1 ton of concentrates.

## HERCULES MINE.

The Hercules mine (Pl. XXVI, *A*) is situated at the head of Gorge Gulch, north of Burke, and, at the time of visit, had been opened by three tunnels, the lowest being at an elevation of nearly 5,500 feet. No. 2 tunnel perforates the ridge and is connected by a tramway with the company's sawmill on the north slope of Tiger Peak. As permission to enter the mine was obtained only on the understanding that the visit should be unofficial and that observations made underground should not be published, the following description contains merely such data as were furnished by the company and such facts as were patent from an inspection of the surface.

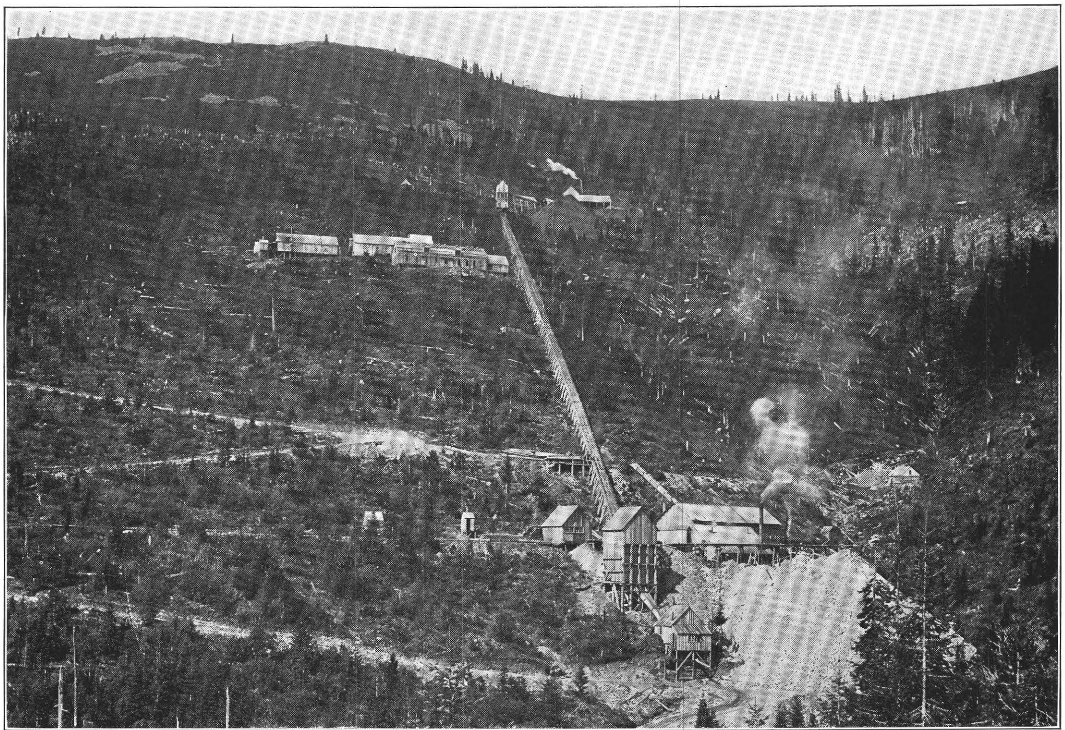
The mine began to ship in 1901 and has proved extremely profitable, the gross value of the ore produced during the first three years exceeding $2,000,000. The statistics of gross production, as furnished by the Hercules Company, are as follows:

*Production of Hercules mine, near Burke, Idaho, 1901–1906.*

| Year. | Lead (pounds). | Silver (fine ounces). | Year. | Lead (pounds). | Silver (fine ounces). |
|---|---|---|---|---|---|
| 1901 | 394,440 | 43,437 | 1905 | 11,856,948 | 729,651 |
| 1902 | 6,034,660 | 406,061 | 1906 | 19,463,622 | 991,033 |
| 1903 | 11,921,303 | 858,355 | | | |
| 1904 | 12,977,703 | 892,301 | | 62,648,676 | 3,920,838 |

Crude ore only had been shipped at the time of visit, large quantities of second-class ore being stored in the stopes and dumps awaiting the completion of a mill. The crude ore was hauled by wagons and sleds to the railway at Burke, about 9 tons being carried by each wagon with its sled trailer. The monthly shipments in 1904 ranged from 1,000 to 1,200 tons. A concentrating mill has since been built and is now in operation.

The general country rock of the Hercules mine is the Burke quartzite. The dumps show, however, that the ore is in part associated with a much decomposed porphyry, apparently of the same type as the dike offshoots from the monzonitic masses along the East Fork of Ninemile



*A.* HERCULES MINE IN 1904, LOOKING NORTHWEST.
Photograph by T. N. Barnard.

*B.* STANDARD-MAMMOTH MINE, CAMPBELL TUNNEL.
The old Standard workings are partly visible on the slope above the modern adit. Photograph by T. N. Barnard.

Creek. The alignment of the tunnels indicates that the ore is related to a fissure zone with the same general trend as the Tiger-Poorman and other Canyon Creek lodes.

The unoxidized ore consists of nearly pure galena, which evidently occurs in considerable masses almost free from gangue, and is readily sorted to a product containing about 50 per cent of lead and 45 ounces of silver per ton. Specimens from the dumps show that the galena, with very subordinate pyrite, chalcopyrite, and sphalerite, have extensively replaced shattered quartzite. The quartzite, near the galena, is usually altered to a dark-green aggregate which the microscope shows to consist of grains of quartz with abundant interstitial green mica somewhat resembling chlorite in habit, but with a stronger double refraction. It seems to be a green biotite, although its identification is not certain. It takes the place of the sericite of the unaltered quartzite and has to some extent replaced the quartz grains. With a little siderite it occurs intimately intercrystallized with the galena. One specimen from the mine shows galena crystallized with a silky asbestiform mineral which is probably anthophyllite, an orthorhombic member of the amphibole group.

Much of the ore of the Hercules is cerusite, which occurs in large masses and clusters of unusually well-developed crystals.

### HECLA MINE.

*Introduction.*—The Hecla mine is situated in the town of Burke, a short distance southwest of the Tiger-Poorman. (See Pl. XXIV, *B*, p. 168.) The original Hecla Mining Company was incorporated in Idaho in 1891, with a capital of $500,000. This company owned the Hecla and Katie May claims, which were worked intermittently until 1897, principally by lessees. During this period ore was extracted to the value of $14,000. In 1897 the company was reincorporated under the laws of Washington with a capital of $250,000. The mine has since been steadily operated and the company now owns 26 claims and has acquired a concentrating mill at Gem. About 125 men are employed underground. The dividends paid up to January 1, 1905, amounted to $310,000, and $240,000 was paid in 1905, making a total to January 1, 1906, of $550,000.[a] The mine affords an excellent illustration of the application of sound financial methods to an industry in which capitalization and optimism are too often absurdly out of proportion to development and dividends.

*Production.*—The production of the Hecla mine since 1897 is given by the following table, the data being furnished by the company:

*Production of the Hecla mine, Burke, Idaho, 1898–1906.*

| Year. | Silver (ounces.) | Lead (pounds). | Year. | Silver (ounces). | Lead (pounds). |
|---|---|---|---|---|---|
| 1898 | 9,696 | 287,387 | 1904 | 447,692 | 15,078,791 |
| 1899 | 67,693 | 2,171,005 | 1905 | 568,685 | 18,016,073 |
| 1900 | 225,721 | 7,170,043 | 1906 | 537,437 | 17,778,942 |
| 1901 | 50,025 | 1,747,936 | | | |
| 1902 | 259,392 | 8,726,743 | | 2,580,163 | 85,197,864 |
| 1903 | 413,822 | 14,220,944 | | | |

*Underground development.*—At the time of visit the mine was opened by three tunnels into the hillside south of Burke and by a shaft with two levels at 300 and 600 feet below the collar. Recently a new level has been opened at a depth of 900 feet. The general plan of the workings is linear and simple. A longitudinal projection is shown in fig. 10 (p. 124). Ore was first discovered in the lowest or No. 3 tunnel, and the upper tunnels, contrary to the usual course of events, were run later. Hoisting is done by electricity generated at Spokane.

*Geological conditions.*—The Hecla lode strikes northwest and southeast and dips at angles ranging from 70° NE. to vertical. The average dip is probably over 80°. The general country rock is the sericitic Burke quartzite. The beds strike nearly northwest and dip notheast at 80°. They are thus approximately parallel to the lode, but the latter actually cuts them, in most places, at a small angle. The lode is intimately associated with a lamphrophyric dike which is

[a] The total dividends in March, 1907, amounted to $1,040,000.

usually about 2 feet wide and has a maximum width of 7 feet. It is not, however, quite simple, as in places it branches or pinches out and is succeeded by a second dike a few feet to one side.

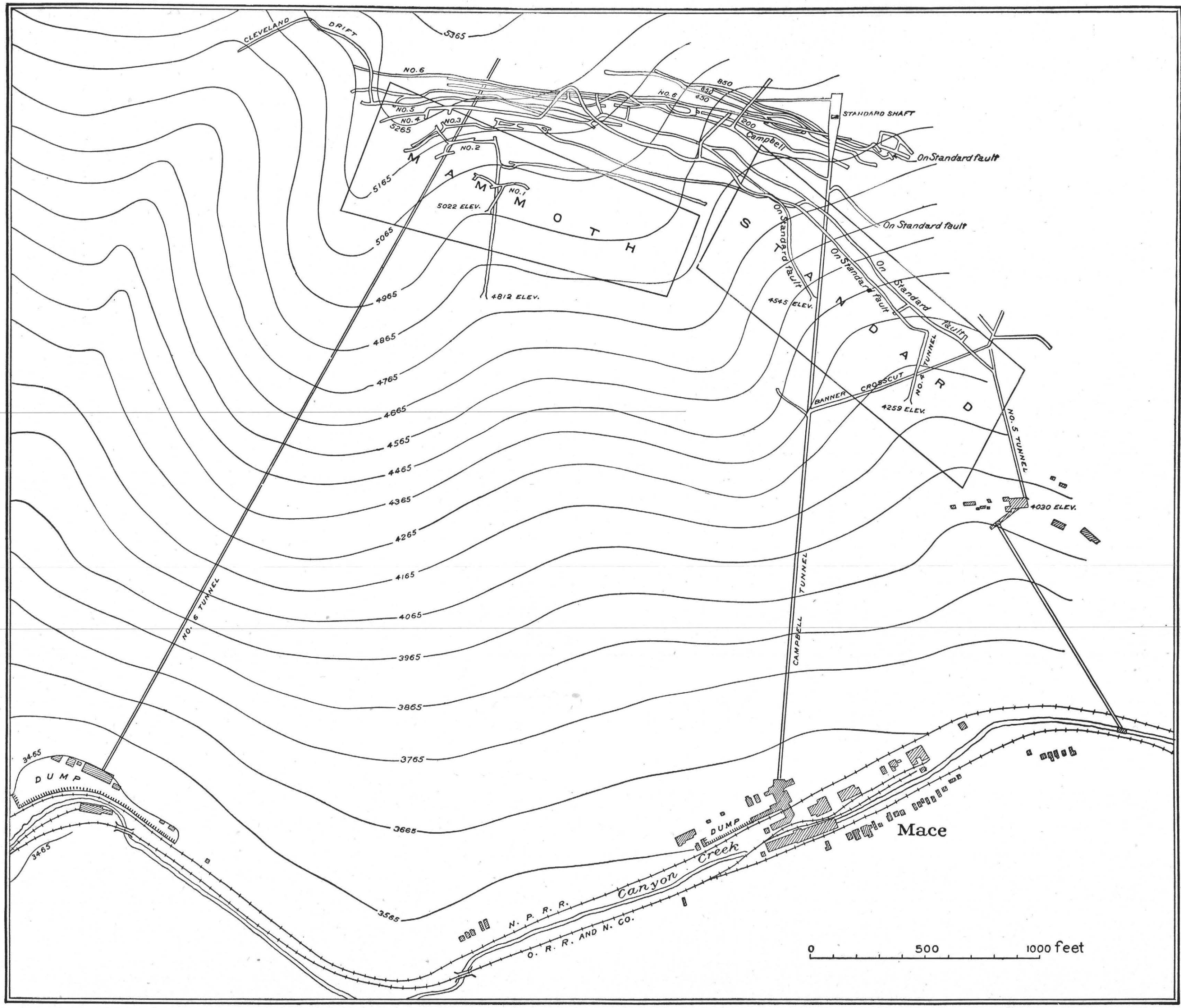
In its freshest condition, the rock of this dike is dark greenish gray and fine grained, the only minerals recognizable with the unaided eye being small prisms of hornblende, specks of pyrite, and scattered irregular grains or granular inclusions of quartz up to an inch in diameter. The microscope shows a holocrystalline aggregate of abundant phenocrysts of hornblende in a groundmass of the same mineral, with a calcic plagioclase in minute laths. Larger phenocrysts, possibly augite, have been completely altered to calcite, serpentine, and secondary amphibole. The rock appears originally to have had some glass in the groundmass, but it is now altered to chlorite. The quartz inclusions are much corroded and embayed and are usually surrounded by reaction rims in which spherulitic quartz appears in the groundmass. The rock is probably an odinite, hornblende being too abundant for kersantite, in which biotite is the principal dark mineral. The quartz grains are presumably not original, but are inclusions derived from the quartzose sediments through which the dike was intruded.

The dike is younger than the ore. At one place on the 600-foot level there was, at the time of visit, an apparent exception to the rule that no ore occurs in the dike. This was a little bunch of unusually dark-colored ore which had apparently formed by partial replacement of the igneous rock. Thin sections show, however, that this ore is really within the quartzitic series and that ore and dike are in sharp igneous contact. The dike rock is more glassy at the contact than elsewhere and sends out little intrusive tongues into the minute fissures or cracks in the ore, which is not perceptibly metamorphosed.

*Structure of the lode.*—The Hecla vein is on the whole a regular lode in which the ore averages between 5 and 6 feet in width and occurs mainly in the quarzite on one or both sides of the dike. To a large extent the ore fills fissures, metasomatic replacement, while by no means absent, being much less noticeable than in most of the Cœur d'Alene mines. Ore nowhere occurs in the dike. Some of the fissures, now filled with nearly solid galena, were in places fully 2 feet in width, and filled fissures 6 or 8 inches wide are fairly common.

The pay shoot, as shown in fig. 10 (p. 124), is about 1,200 feet in extreme length and has apparently a vertical pitch. On all the levels the first ore is reached between 700 and 800 feet southeast of the shaft, the dike where first crosscut being unaccompanied by ore. This ore is here on one side and there on the other side of the dike. Where it pinches out on one side it is recovered by crosscutting through the dike. The ore usually "comes in from the foot wall," as the miners say, the meaning of the phrase being that many stringers of ore branch from the lode into the foot wall, toward the west. As in all the Canyon Creek mines, nearly horizontal but irregular stringers of quartz are abundant in the quartzite near the lode, particularly in the hanging wall. They pinch out a few feet away from the ore. Some of these stringers are clearly older than the dike, as they are cut off abruptly at its walls and no similar stringers are known within the igneous rock. They may possibly be younger than the ore. Flat seams of ore make out here and there into the quartzite, but nowhere extend for more than a few feet from the main lode.

*Character of the ore.*—The average grade of the Hecla ore in 1905 was 9.2 per cent of lead and 58 ounces of silver. About 100 tons of picked crude ore is shipped each month and the balance, about 265 tons a day, furnishes from one-sixth to one-fifth of its weight in concentrates. The ore consists chiefly of galena accompanied by very subordinate sphalerite and pyrite. A little quartz is locally crystallized with the galena and a few small vugs contain rhombs of calcite. True gangue minerals are decidedly subordinate, the ore consisting principally of galena and unreplaced quartzite. At the east face of the 600-foot level there was, at the time of visit, a solid vein of massive galena from 2 to 3 feet wide, inclosing little blebs of sphalerite and a few crystals of pyrite. Siderite, so characteristic of the Wardner and Mullan mines, was not seen in the Hecla except as a microscopic constituent of some varieties of the ore.




MAP SHOWING PLAN OF DEVELOPMENT OF STANDARD-MAMMOTH MINE.

From the company's surveys. Top is north.

## STANDARD-MAMMOTH MINE.

*Introduction.*—The Standard-Mammoth mine, owned by the Federal Mining and Smelting Company, and by them designated "the Mace mines," is situated about a mile west of Burke, on the south slope of Custer Peak. Up to the time of their purchase by the Federal Company, the Standard and Mammoth were separate mines on contiguous portions of the same lode.

The Mammoth ore body was entered in September, 1890, and shortly afterward the mine began shipping by pack horses to the railway below Burke. By the end of the year the output amounted to about 60 tons of rich ore, averaging about 55 per cent of lead and $89 in silver per ton.

The Standard claim was located in 1887, but did not become productive until after the Mammoth, for, unlike the latter mine, the Standard had no large bodies of oxidized ore near the surface. Both mines have been highly profitable. Prior to absorption by the Federal Company the Standard paid dividends amounting to $2,945,000 and the total dividends of the Mammoth probably exceeded $1,500,000. The price paid for the mines by the Federal Company is commonly understood to have been $3,000,000 each.

*Production.*—According to J. R. Finlay, the Standard-Mammoth lode produced up to the end of 1901 lead and silver of the gross value of about $11,000,000 and paid at least $3,000,000 in dividends. In 1902 the Mammoth produced 74,994 tons of ore, of a gross value of $921,611, and the Standard 155,525 tons, of a gross value of $1,321,976. From the consolidation under the Federal Company to the end of 1905 the Standard-Mammoth produced 850,102 tons of ore containing 109,697,511 pounds of lead and 4,473,860 ounces of silver.

The ore produced in 1906 was reported at 334,403 tons, of a gross value of $3,969,941.46.

*Underground development.*—The Mammoth lode outcrops nearly 1,500 feet above Canyon Creek and was originally worked through the high-level tunnels designated as No. 1 and No. 2 in Pl. XXVII. Later the vein was tapped by No. 4 and No. 5 tunnels through the Standard ground. In 1896 the Campbell tunnel (see Pl. XXVII), from Canyon Creek, reached the vein and became the principal adit of the Standard mine. No. 6 tunnel, with its portal 3,000 feet west of the Campbell adit and 131 feet lower, was subsequently driven to give access to the part of the vein in Mammoth ground. At the present time men and supplies enter by the Campbell tunnel and ore is run out through No. 6 tunnel and shipped by rail to the combined mills at Wallace, shown in Pl. XXVII, *A*. An underground shaft near the end of the Campbell adit gives access to five levels below No. 6 tunnel, as shown in fig. 9 (p. 124). The lowest level at the time of visit was 1,050 feet below the collar of the shaft. The mine is well equipped with electric haulage in both adits and with a Corliss hoisting engine, similar to that of the Tiger-Poorman mine, installed in the underground shaft station.

*Geological relations.*—So far as could be determined the Standard-Mammoth mine is entirely within the Burke formation. The prevailing rocks are fine-grained sericitic quartzites. The general strike of the beds is apparently about 39° west of north, the dip ranging from 45° to 75° SW. Locally they show imperfect slaty cleavage trending nearly northwest, with the dip about vertical.

In a few places in the mine, as in the stopes above the Wilson level, small quantities of a dark, decomposed dike rock occur with the ore, as if there had originally been a narrow dike, similar to that of the Hecla, along the line of the lode. A small dike, which is considerably altered but which is apparently composed of a similar rock, is cut in the Banner crosscut from the Campbell tunnel.

*The lode.*—The Standard-Mammoth vein strikes N. 83° W. and dips to the north at an average angle of 80°. The attitude of the beds has apparently had no influence on the formation of the lode, which cuts them at various angles. On the east the ore ends at a strong fissure which is recognizable on practically all the levels and has usually been regarded as a fault of later age than the ore. This fissure, which may be conveniently designated the Standard fault, strikes northwest and dips northeast at an angle between 65° and 70°. Its relation to the Standard vein is shown in fig. 9 and in Pl. XXVII, where it is seen that the fissure meets the vein obliquely and cuts it off farther east on each successive level from the surface down. Tunnels 3, 4, and 5 all follow this fault for some distance. The Banner crosscut from the Campbell tunnel, which was an attempt to find the continuation of the Standard ore, also furnishes a good exposure of the fault and of some additional fissures lying just northeast of it and dipping in the opposite direction.

On the west the stopes are not so sharply limited. Below No. 6 level the Mammoth ground is as yet undeveloped and the total length of the lode or ore body is consequently unknown. Above that level the ore becomes narrower and the lode fissures less distinct as one goes west. The west face of No. 6 level shows merely a narrow fissure, about an inch wide, carrying some siderite and quartz and accompanied by some shearing of the quartzite. The most westerly ore in the mine occurs on No. 5 level, about 800 feet west of the Peterson raise (fig. 9). This is apparently an isolated body of small size and is cut off at its western extremity by a fissure striking nearly north and south and dipping to the west. This fissure and apparently others intersecting it at small angles have been followed in the curved Cleveland drift to the north of this ore for a distance of 300 or 400 feet (Pl. XXVII). A crosscut was then run to the southwest and an attempt made to pick up the Mammoth vein by diamond drilling. At the time of visit these efforts had met with no success and the outlook for finding ore in this direction does not seem to be promising. As shown by fig. 9, the total length of the ore body, or of the generally productive part of the lode, above No. 6 tunnel is approximately 1,800 feet. The probabilities are that this length will be considerably exceeded when the development of the lower Standard levels is carried westward into the Mammoth territory.

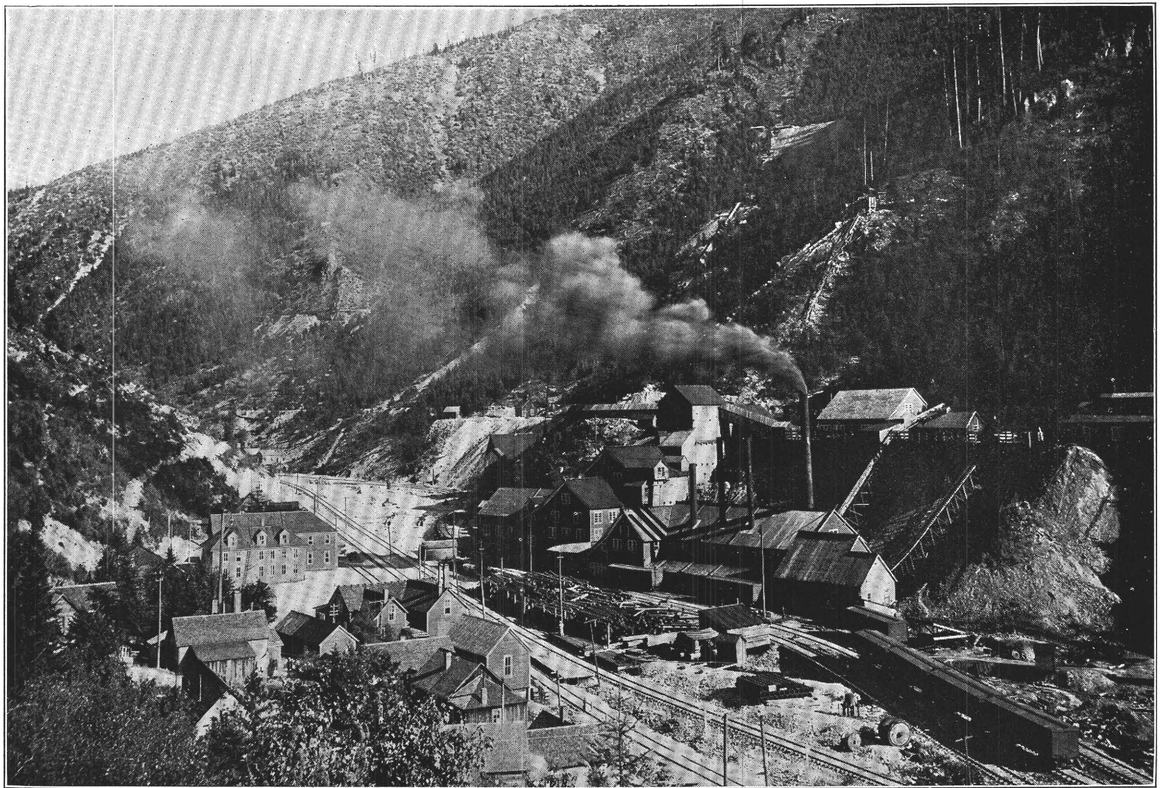
The lode is structurally a zone of combined fissuring and shearing in which the ore occurs partly as distinct stringers and partly as irregular replacements of the sheared and crushed quartzite. In many places a single face of ore will show both types of deposition. In the veinlets or stringers the siderite has usually crystallized near the walls and the quartz near the middle of the fissure. A very characteristic feature of the lode is the presence of numerous nearly horizontal stringers of quartz which are later than the mass of the ore and produce a striking cross-barred effect in the faces of the stopes, as illustrated in fig. 13 (p. 128). Some of them extend into the country rock on both sides of the lode, but these are usually larger in the ore than in the quartzite and generally do not persist for more than a few feet into the country rock. These cross gashes seem to have been formed by shearing movement along the vein after the bulk of the ore had been deposited, the comparatively brittle and massive ore being fissured, while the quartzites, which are as a rule rather fissile and slaty near the ore, were deformed by slipping along the shear planes. This or a similar movement seems to have continued to recent times and is probably still in progress. There is usually a soft gouge seam along the vein, in some places in the ore and in others on one side of the lode. True walls are lacking, as in most of the Cœur d'Alene veins, and the ore is as a rule from 5 to 15 feet wide. The widest and best ore appears to occur near the Standard fault.

The generally simple tabular form of the lode is interrupted here and there by horses, most of which are indicated by the plans of the levels in Pl. XXVII.

*Character of the ore.*—A large proportion of the Standard-Mammoth ore consists of galena with some sphalerite, in a gangue of quartz and siderite. Less abundant or less widely distributed minerals are tetrahedrite or chalcostibite (?), chalcopyrite, pyrrhotite, and pyrite. Tetrahedrite and chalcopyrite seem rather more abundant above the 650-foot level than below it, and pyrrhotite is certainly a more noticeable constituent of the ores on the 1,050-foot level than above. Sphalerite and pyrite also, so far as could be judged by an examination of the stopes at but one stage of development, are becoming rather more abundant with increase of depth.

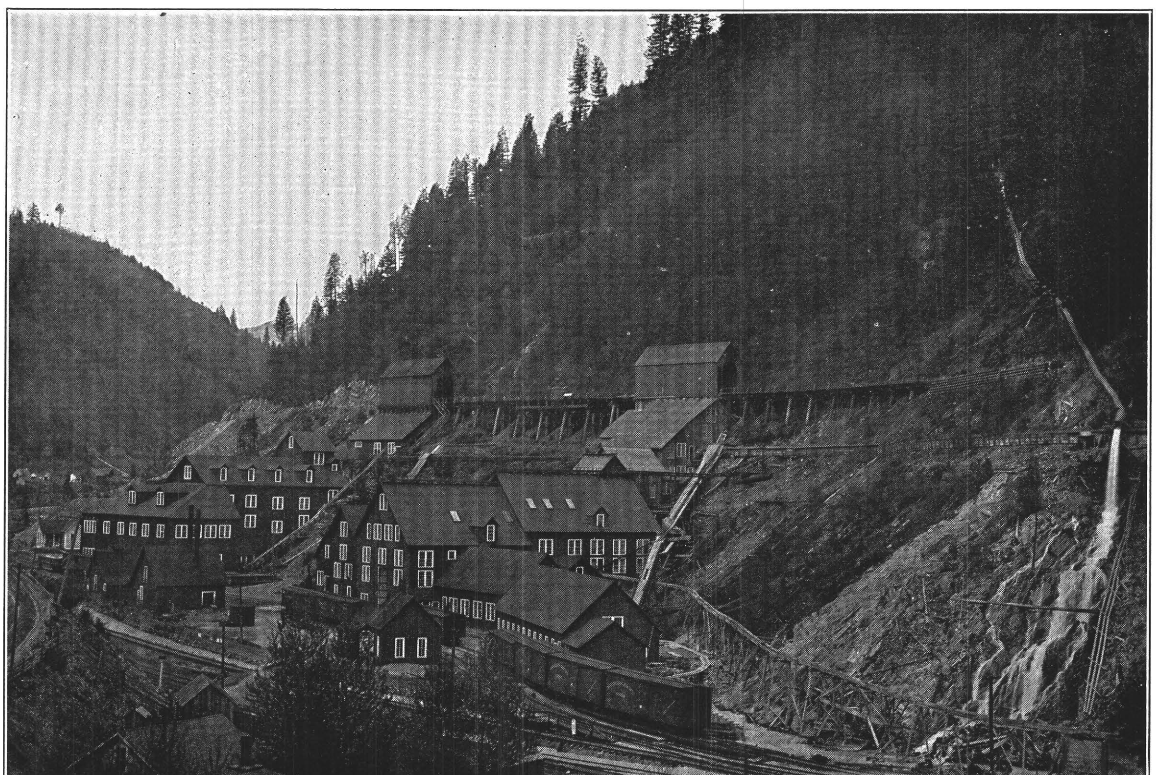
Some of the quartz is contemporaneous with the siderite. The mineral occurs, however, in later veinlets which cut the mass of the ore and in places contain tetrahedrite or chalcostibite.

The ore as delivered at the mills carries about 7 per cent of lead and between 6 and 7 ounces of silver. The concentrates contain from 45 to 52 per cent of lead and 40 to 45 ounces



*A*. STANDARD-MAMMOTH MILLS, ON CANYON CREEK NEAR WALLACE.

Showing situation with reference to water power and railway.



*B*. HELENA-FRISCO MINE AND MILL.

The upper tunnels are on the Black Bear vein.

of silver per ton. The ore is thus of much better grade than that from the Tiger-Poorman mine. Here, as elsewhere in the district, tetrahedrite and a high proportion of silver go together.

### HELENA-FRISCO MINE.

*Introduction.*—The Helena-Frisco mine (Pl. XXVIII, *B*) is situated on the south side of Canyon Creek, between the little settlements of Black Bear and Gem, and is a consolidation of the Black Bear, San Francisco, and Gem of the Mountain mines, with several other claims of less note. The three claims mentioned were located in 1884 and were separately worked up to about 1901, the Gem being latterly known as the Milwaukee mine, from its ownership by the Milwaukee Mining Company. At the time of visit lessees were working in some of the tunnels, but the Frisco and Gem shafts were filled with water and many parts of the upper workings were also inaccessible. Recently the mine has been unwatered and in 1906 the company began sinking to open a new level.

*Production.*—The production of the mines prior to 1897 could not be ascertained, although the company's records show that approximately 50,000 tons of concentrates were shipped from the Frisco mine between 1892 and August 1, 1897. The production from the latter date to the cessation of the company's operations in 1903 is shown in the following table. Very little work has been done in the Gem mine for the last ten years and the bulk of the production tabulated came from the Frisco mine.

*Production of Helena-Frisco mine, near Gem, Idaho, 1897–1906.*

| Year. | Ore raised (short tons). | Gross contents. | | Tons of ore required to make 1 ton of concentrates. |
|---|---|---|---|---|
| | | Lead (pounds). | Silver (fine ounces.) | |
| 1897 (5 months) | 66,363 | 7,313,137 | 284,564 | 8.83 |
| 1898 | 186,117 | 21,334,569 | 859,871 | 8.60 |
| 1899 | 401,468 | 42,307,670 | 1,636,051 | 10.34 |
| 1900 | 188,598 | 17,514,835 | 512,749 | 9.90 |
| 1901 | 62,100 | 6,340,007 | 180,841 | 9.15 |
| 1902 | 18,858 | 1,535,348 | 45,095 | 9.39 |
| 1903 | 98,378 | 8,950,788 | 267,293 | [a] 10.5 |
| 1904 | 14,970 | 1,460,483 | 48,945 | ........... |
| 1905 | 5,013 | 1,191,509 | 32,178 | ........... |
| 1906 | 775 | 779,978 | 29,214 | ........... |
| | 1,042,640 | 108,728,324 | 3,896,801 | [b] 9.53 |

[a] About. [b] Average.

*Underground workings.*—The principal adit is No. 3 tunnel or 600-foot level of the Frisco mine (Pl. XXIX), which runs southeastward from the mill for about 1,100 feet to a large underground station. Here the Frisco shaft, 1,400 feet deep, gives access to seven levels at vertical intervals of 200 feet. Some of the Frisco levels crosscut into the Black Bear and Gem territories, but the ore bodies of the three mines (fig. 11, p. 125) are quite distinct and there is practically no connection between the three sets of workings, as may be seen from Pl. XXIX. The Black Bear vein is opened by four tunnels. The Gem has three tunnels and three lower levels, which are reached through a 500-foot winze from the lowest tunnel. The new level, for which sinking began in 1906, will be 1,600 feet below the adit level.

*Geological relations.*—Such parts of the mine as could be seen at the time of visit are in the Burke formation and in syenite and monzonite. The ore, however, is entirely confined to the quartzite, which exhibits pronounced contact metamorphism near the igneous rock and at the contact is altered to a dark, vitreous hornstone which the microscope shows to be an aggregate of quartz, biotite, garnet, and muscovite, with some pyrite. The biotite, as seen in section, is deep green or yellowish brown according to its optical orientation.

The contact between the Burke quartzite and the syenite marks the west end of the Gem vein. In some places the ore extends to the contact. In the igneous rock, however, the vein splits into irregular barren fissures and its identity is soon lost. (See fig. 20.) All three lodes are well-marked fissure veins which cut the quartzite beds and show various degrees of replacement.

In No. 4 tunnel of the Black Bear mine the vein is crossed nearly at right angles by two small dikes of a dark rock resembling that of the Hecla and Standard dikes. These dikes clearly cut the vein, although at a barren place, offsetting it for about a foot. Under the microscope the rock shows a groundmass of hornblende prisms in a turbid greenish base which may once have been glass but which now shows a faint, shadowy double refraction and a minute granular texture under high magnification. The phenocrysts consist of a mineral somewhat suggestive of feldspar in outline but wholly altered to sericite, and of augite partly altered to a greenish serpentine-like product that is not readily distinguishable from some of the groundmass. The groundmass shows a streaky texture, suggesting that of the vitrophyres and caused in part by the better development of the hornblende crystals in some portions of the groundmass than in others. The rock contains no feldspar. It is impossible to classify this rock satisfactorily without more chemical work than is warranted by the decomposed state and the small mass of the dikes. The groundmass is suggestive of monchiquite. On the other hand, the sericitic pseudomorphs which play the part of phenocrysts may have been originally feldspar. The rock may provisionally be classed with that of the Hecla dike as an odinite. The chief interest attaching to the dikes is that they are clearly later than the Black Bear vein, although there may have been some deposition of ore after their intrusion, as they do not actually cut ore.

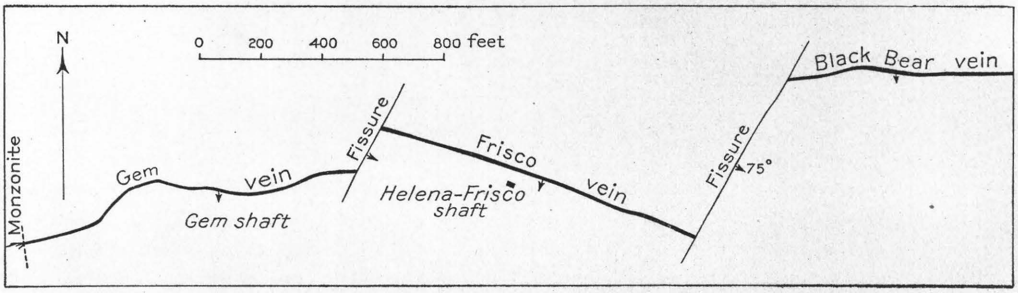


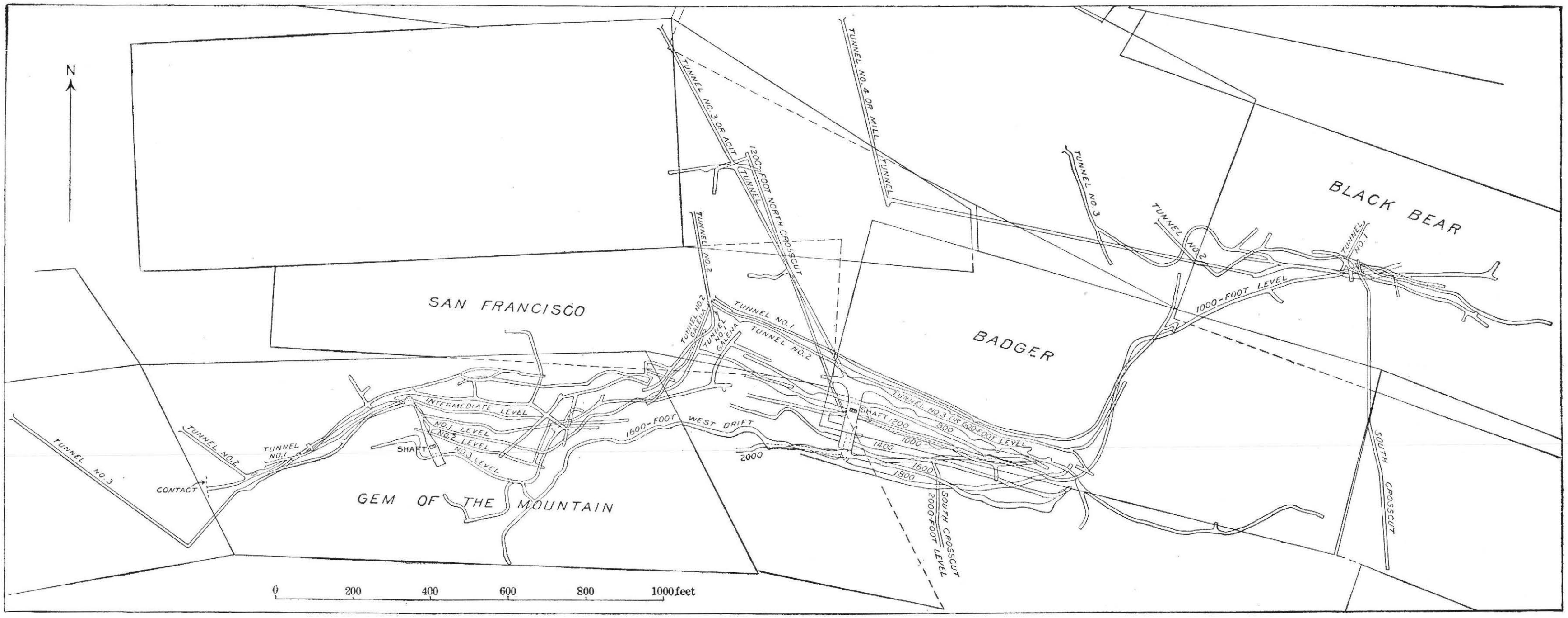

FIG. 20.—Plan of veins in the Helena-Frisco mine.

*Vein system.*—The vein system of the Helena-Frisco group is one of the most interesting in the district, and it is to be regretted that the state of the mine did not permit a satisfactory study of structural relations. As indicated by Pl. XXIX and shown more simply in fig. 20, the Black Bear, Frisco, and Gem veins are apparently parts of a single nearly east-west fissure zone that has been dislocated by faulting. This view was held by Finlay[a] and by Lindgren.[b] For reasons that are fully discussed on pages 120–121, this conclusion, however, seems questionable. The apparent cross faults are probably fissures that, so far as their initial opening is concerned, were contemporaneous with the veins. This view seems more in harmony with the different character of the Frisco and Black Bear veins, with the lack of evidence of great displacement along the cross fissures and with the fissure relations in the Standard-Mammoth, Tiger-Poorman, and Hercules mines. But unfortunately conclusive exposures of the cross fissures were not accessible at the time of visit.

The Frisco vein is fairly regular. It strikes N. 72° W. and from the surface to the 1,800-foot level dips to the south at angles ranging from 80° at the west end of the lode to 83° or more at the east end. Below the 1,800-foot level the vein apparently dips northward and is less regular in trend. The mine map indicates that the vein is cut off on the west at about the same distance from the shaft on each level. There is presumably a cross fissure here, separating the Frisco from the Gem lode, as indicated in fig. 20. The workings in this part of the mine, however, could not be entered in 1904, and the fissure was not actually seen.

[a] Trans. Am. Inst. Min. Eng., vol. 33, 1903, p. 248.

[b] A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, p. 111.




PLAN OF PRINCIPAL UNDERGROUND WORKINGS OF HELENA-FRISCO MINE.

From the maps of the company.

Similarly, the drifts east of the shaft all terminate at about the same distance or, where not mere crosscuts, they are deflected sharply toward the Black Bear vein. The vein plainly ends against a fissure or fissure zone which in 1904 was accessible at one point in No. 3 Frisco tunnel. The fissure, where seen, is filled with soft gouge, strikes apparently about N. 35° E. and has a local dip of 75° SE. This fissure could not be identified with certainty in the Black Bear workings, although it possibly crosses No. 4 tunnel about 200 feet west of the point where the tunnel cuts the vein. The vein itself has apparently never been explored westward to the plane of the supposed fault.

The Black Bear vein is less regular than the Frisco. The general strike is east and west, but the different tunnels show considerable divergence. The dip is south at the west end of the vein, but changes to north at the east end.

The Gem vein is also irregular. The average or general course is a little south of west. On the west, near the syenite, the lode is practically vertical. In the eastern part of the Gem workings the dip is to the south at an angle of nearly 70°.

*Occurrence and character of the ore.*—The Frisco vein has been described by Lindgren[a] as follows:

The vein, which cuts the quartzite in strike and dip, has a course of N. 80° W., and a variable southwest dip averaging 70°[b] and gradually straightening on lower levels. The ore averages 10 to 12 feet in width, and is taken out uniformly. The foot wall is very poorly defined; the hanging wall is also often indistinct, though usually roughly indicated. Sometimes every indication of geometrical walls is absent. The rock is hard and compact, even within walls. Within the width of 12 feet are irregular streaks of fine-grained steely galena and blende, occasionally a couple of feet thick. Pyrite, and in places chalcopyrite, are sparingly represented. The gangue is finely divided siderite and a little quartz, the latter in narrow and irregular seams. The vein is clearly the result of replacement of quartzite by galena, zinc blende, and siderite, along tight fault planes. The vein system of which the Helena-Frisco forms a part continues for 6 miles and is faulted at several places by later fissures striking north-northeast.

This description probably applies to the Frisco vein, particularly as seen in the lower levels, where work was in progress at the time of Mr. Lindgren's visit. It may be added that pyrite is fairly abundant—perhaps more so than in the other Canyon Creek lodes, and that it is accompanied by some pyrrhotite. Siderite, on the other hand, is not abundant and in the parts of the vein accessible in 1904 the gangue mineral is quartz, with a little sericite, no siderite being present. Replacement of the minutely sheeted and sheared quartzite by ore is very well shown.

The ore of the Black Bear vein, as seen about 70 feet above No. 4 tunnel, consists of quartz and galena with practically no sphalerite or pyrite, although these minerals appear in some of the lean portions of the vein. It fills a simple fissure, from 2 to 3 feet wide where stoped, and, unlike the Frisco lode, shows very little evidence of replacement. The ore is closely adherent to its walls and shows no evidence of disturbance since its deposition. According to Mr. G. Ehrenberg, assistant manager, the Black Bear ore contains more lead but a smaller relative proportion of silver than the Frisco lode. The parts of the two veins seen in 1904 are so markedly different in character as to cast much doubt on the hypothesis that the lodes were once continuous.

The ore of the Gem vein, on the other hand, closely resembles the Frisco ore, galena, sphalerite, pyrite, chalcopyrite, pyrrhotite, and quartz forming a lode that is clearly for the most part a replacement of the sheared and fissured quartzite. Here also siderite is absent or very subordinate in the ore now visible, although it may have been present in the abandoned and inaccessible stopes worked about ten years ago.

The pay shoot of the Frisco lode, as may be seen from fig. 11 (p. 125), was almost coextensive with the vein down to the 1,600-foot level. Below that level it seems to have diminished in size. Its maximum length was a little less than 1,000 feet.

The Black Bear pay shoot is smaller and apparently contained little of value where cut by the 1,000-foot level from the Frisco shaft.

In the Gem workings there appear to be two general shoots of ore, converging downward. The main shoot (fig. 11) attained its maximum length of 800 feet on tunnel No. 2 level.

[a] Op. cit., p. 111.

[b] Nearer 80°.—F. L. R.

The smaller eastern pay shoot has apparently not been found below No. 2 level, and the size and tenor of the main shoot on No. 3 level were evidently not such as to encourage further work.

The ore of the Helena-Frisco group is on the whole of low grade. In 1903 its average tenor was 4.5 per cent of lead and 2.7 ounces of silver per ton. Operation under such conditions was no longer profitable. In 1899, when the output from the mine reached its maximum, the ore averaged 5.2 per cent of lead and 4 ounces of silver per ton, and in 1898 the average was 5.7 per cent of lead and 4.6 ounces of silver.

No oxidized ore was seen in 1904, although the Frisco mine is known to have produced some rich cerusite ore, with wire silver, in 1889.

## UNION MINE.

The Union property, no longer worked, is on the south side of Tiger Peak, northwest of the Tiger-Poorman workings. The country rock is Burke quartzite and the lode is apparently on the same fissure zone as the Tiger-Poorman, although the ore bodies of the two mines are not continuous.

The old tunnels of the Union have apparently been long abandoned and were not accessible in 1904. The dumps show that the galena was associated with much pyrite and sphalerite in a quartz and siderite gangue.

## BELL MINE.

The Bell mine, situated in Bell Gulch, southeast of Gem, first attracted attention in 1887, when some rich ore was discovered and the mine was bonded for $60,000. It was never very productive, however, and in 1904 the workings were idle.

The mine was not examined, but the maps indicate a lode striking nearly east and west. The lower tunnel is a crosscut for 800 feet and connects with a drift about 1300 feet in length along the general line of the lode. The country rock is the Burke formation.

# CHAPTER X.—DETAILED DESCRIPTIONS OF THE LEAD-SILVER MINES ON NINEMILE CREEK.

## INTRODUCTION.

The Ninemile Creek group of mines includes the Sunset, on Sunset Peak; the Custer, on the west side of Custer Peak; the Sixteen-to-One,[a] three-fourths of a mile east of Dobson Pass; the Granite,[a] about a mile south of the Sixteen-to-One; and the California Consolidated,[a] on Blackcloud Creek. All are small mines, although the Custer and Granite have produced considerable ore and the Custer fifteen years ago was one of the principal mines in the district. In 1904 prospecting was in progress at the Sixteen-to-One and Granite and lessees were working the Custer and California Consolidated on a small scale, but the Sunset was idle.

## CUSTER MINE.

*Introduction.*—The Custer mine is situated high up on the west side of Custer Peak, on a zone of fissuring which is apparently the same as that of the Union and Tiger-Poorman mines. It seems to have first attracted attention as a promising prospect in 1888, and two years later had become one of the most important mines in the district. At this time it shipped daily about 20 tons of crude ore said to have averaged 65 per cent of lead and 55 ounces of silver per ton. Subsequently an aerial tramway about 2 miles in length was constructed to convey the ore to a concentrating mill on Ninemile Creek. Little work has been done of late years, although lessees were getting out small quantities of ore in 1904.

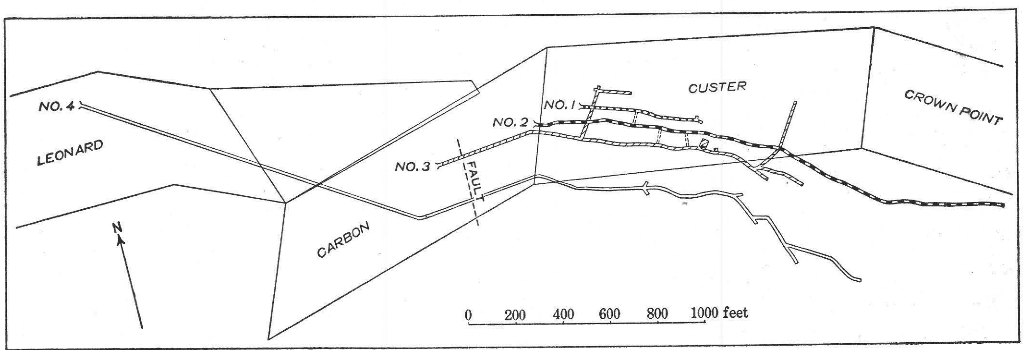



FIG. 21.—Plan of the underground workings of the Custer mine.

*Production.*—According to Mr. E. H. Moffitt, one of the owners, the Custer has produced ore of the total gross value of $600,000. Detailed statistics are not available.

*Underground development.*—As shown in fig. 21, the Custer is opened by four tunnels. No. 1 is at an elevation of nearly 5,900 feet, No. 2 about 125 feet lower, and No. 3 about 200 feet below No. 2. No. 4 tunnel is at an elevation of approximately 4,780 feet. Tunnels 2 and 4 were the only ones open in 1904.

*Geological relations.*—The Custer workings are probably entirely in the quartzites of the Burke formation. The first 1,200 feet of the No. 4 tunnel traverses hard white quartzites which are cut by several dikes of monzonitic porphyry. The tunnel then crosses a strong fault breccia, at least 50 feet wide, east of which the beds are darker and apparently belong to the lower part of the Burke formation. Neither the strike nor the dip of the fault could be ascer-

[a] Since the greater part of this report was written the official names of these mines appear to have been changed. The Granite has become the Success; the Sixteen-to-One the Rex; and the California Consolidated the Tamarack and Chesapeake. Such changes, as a rule, are regrettable and are sources of vexation to all except the new owners of the renovated property. Fortunately the great mines of the world have usually proved as stable in name as in productivity.

tained from the exposure available. It is reported to cross No. 3 tunnel about 100 feet from its portal, which, if true and if the fault is nearly vertical, would indicate a north-south trend. The little patch of Prichard slate mapped by Mr. Calkins (Pl. II, in pocket) on the northwest slope of Custer Peak is bounded on the west by a fault which is probably the one cut in No. 4 tunnel. The presence of this Prichard area at this place indicates that the beds exposed in the tunnel east of the fault are near the base of the Burke formation and may be in part Prichard. The Custer vein has never been found in No. 4 tunnel, which, as is evident from fig. 21, has swung from one indistinct barren fissure to another in a vain search for ore.

*The lode.*—The Custer vein, as seen in No. 2 tunnel, is a well-defined fissure vein which strikes N. 70° W. and dips to the south at a high angle. It cuts the quarztite and shows very distinctly the replacement of quartzite by galena, secondary quartz, and a little chalcopyrite and pyrite. Siderite was not noted either in the mine or in thin sections of the ores. Most of the former stoping seems to have been done above No. 2 tunnel, but lessees are now sinking a winze on ore. The lode shows some movement since the ore was deposited and the galena is in places partly altered to cerusite.

Thin sections of the poorer ore show a partial replacement by galena of fine-grained quartzite, with abundant interstitial sericite. The quartz near the galena has usually recrystallized into a coarser aggregate than in the original quartzite and is free from sericite.

## GRANITE MINE.

*Introduction.*—The Granite or Success mine is situated on the southeast side of East Fork of Ninemile Creek, in the prominent tongue of the Prichard rocks that extends into the syenite mass north of Gem. Its relation to this intrusive rock and the unusual shape and character of its ore bodies give to this mine greater interest than pertains to others of more economic importance.

The Granite claim was located in July, 1885, and was sold about two years later for $18,500. Shortly after the sale it began shipping ore and has produced in all about $800,000 gross and has paid about $200,000 in dividends. The known ore bodies were exhausted about the year 1890, but in 1904 development 400 feet below the old stopes revealed some additional ore and according to recent accounts the mine, now operated by the Success Mining Company, has resumed production with zinc as an important part of the output. A mill of 150 tons capacity has been erected since the date of visit and furnishes a concentrate carrying 45 per cent of zinc. The production for 1906 is given as 10,289 short tons of ore carrying 22,840 fine ounces of silver, 685,800 pounds of lead, and 1,929,000 pounds of zinc.

*Underground development.*—The mine workings, as shown in fig. 22, are confined to a small area and are very irregular. There are two upper tunnels, about 200 feet apart, with an intermediate level. All the ore mined prior to the cessation of operations fourteen years ago came from the ground above No. 2 tunnel. No. 3 tunnel is 418 feet below No. 2, entering the hillside 50 feet or so above East Fork of Ninemile Creek.

*Occurrence of the ore bodies.*—The ore of the Granite mine is exclusively confined to the tonguelike mass of slate and quartzite, which, as shown in Pl. II (in pocket), extends almost entirely across the large intrusive body of monzonite north of Gem. There is no vein, the ore occurring in masses of irregular form and various sizes, which are clearly for the most part replacements of the quartzite in places where the latter has been most thoroughly fissured. The ore masses, in so far as they exhibit any regularity at all, are suggestive of lenses standing on edge, the shortest diameter of nearly every mass being approximately horizontal. In the upper workings the ore consisted chiefly of galena carrying about three-fourths of an ounce of silver to each unit of lead. It is said that almost all the ore bodies contained an increasing proportion of sphalerite in their outer portions, and that where the ore finally graded into country rock the principal constituent was pyrite. Although a carload of good ore was shipped from the lower or No. 3 tunnel in 1904, the bodies thus far opened on this level contain more sphalerite and galena than above and its profitable working will probably depend largely on utilization of the zinc. The ore usually contains a little chalcopyrite, and probably pyrrhotite, although none of the specimens collected show the latter mineral. There is very little gangue other than the mineralized quartzite. In places a little quartz is crystallized with the galena, but siderite seems to be entirely absent.

The ore is strictly confined to the sedimentary rock, which probably belongs to the Prichard formation, although its quartzite character shows that it is near the top of the formation and suggests that it may be in part Burke. The general relation of the ore bodies to the quartzite and monzonite is shown in fig. 22. The apparent extension of the ore into the igneous rock suggested by the figure is due merely to the fact that the rather irregular intrusive contact is approximately outlined for No. 2 level only, whereas the ore bodies shown in plan occur at various levels.

The quartzite all shows some metamorphism due to the intrusion of the monzonite. The general character of this alteration has been fully described by Mr. Calkins on pages 49 to 52. In consequence of it, the rock usually has a green color, due to the development of minute grains of pyroxene, or in a few places a pink tint where garnet in microscopic crystals is the principal contact-metamorphic mineral. The microscope shows that the quartzite is completely

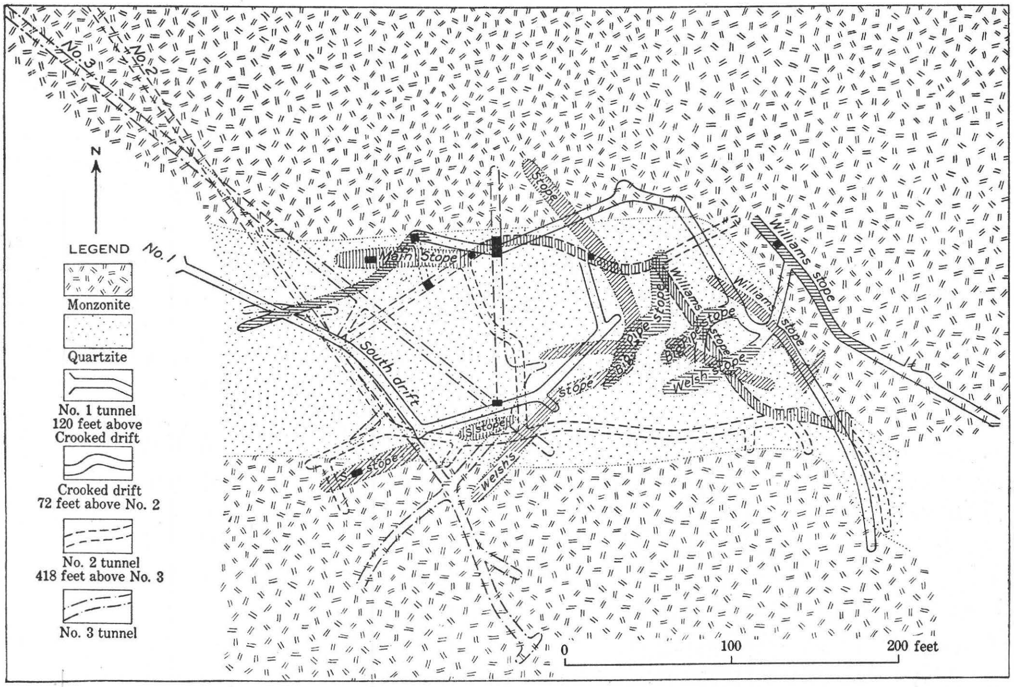



FIG. 22.—Plan of the Granite mine, showing geological relations.

recrystallized to an aggregate of interlocking quartz grains which inclose variable proportions of pale-green monoclinic pyroxene, green-brown biotite, white mica (probably muscovite), and garnet.

The association of the ore minerals with the metamorphic silicates is so close that the conclusion of their contemporaneous genesis is unquestionable. Irregular bunches of ore, which have evidently formed by replacement of the quartzite, show in some cases peripheral gradation from galena to sphalerite and pyrite, and locally these minerals in turn pass into an outer envelope of garnet, as is shown in Pl. X, *C* (p. 98). The microscope reveals the presence here and there of a little carbonate, apparently calcite.

The foregoing characteristics indicate that the ore of the Granite mine was deposited shortly after the intrusion of the monzonite and is a phase of contact metamorphism. The quartzite tongue was irregularly cracked by the intrusion and ore deposition worked out from these fractures contemporaneously with the more extensive change of the impure quartzite to a hornfels, or compact aggregate of quartz and metamorphic silicates. All the ore is "frozen," as the miners say, to the country rock and there has been very little fissuring since its deposition.

## SIXTEEN-TO-ONE MINE.

The Sixteen-to-One or Rex mine is situated on the northwest side of the main or East Fork of Ninemile Creek, about a mile east of Dobson Pass. It became productive early in 1900, but the total output was not ascertained. The property was recently purchased by Messrs. Finch & Campbell for a reported price of $800,000, and at the time of visit in 1904 prospecting was in progress to find the continuation of the ore body on the lower of the two tunnels by which the mine is opened.

The ore occurs in dark slates and thin-bedded quartzites belonging in the upper part of the Prichard formation, and not far from the contact with the same body of monzonite that surrounds the Granite ore bodies. Both tunnels cut a dark dike, from 20 to 30 feet wide, which strikes in a general northwest direction and dips toward the southwest. All the ore so far found lies west of this dike.

The contact of the monzonite with the Prichard beds is well shown in the lower tunnel. It is sharply defined and irregular, the slates and quartzites in its vicinity being altered to hornfels. Both the intrusive rock and the sediments contain a good deal of disseminated pyrite near the contact.

The dark dike, which is a prominent feature of the mine, is composed of a fine-grained, even-textured rock which sparkles with tiny prisms of hornblende. The microscope shows that it is holocrystalline, with small phenocrysts of olivine which have been completely altered to aggregates of fibrous serpentine, greenish biotite, a brightly polarizing micaceous mineral which is probably iddingsite, and specks of magnetite or chromite. The most abundant mineral in the groundmass is a green-brown amphibole in crystals that are usually automorphic in the prism zone. There is also present a calcic labradorite which is subordinate to the amphibole and a few grains of nearly colorless augite. A chemical analysis of this rock seemed scarcely warranted and its precise classification remains a little doubtful. It is evidently near a camptonite.

All of the ore lies west of the dike, along a fissure zone which strikes in general N. 77° W. and dips toward the north. Along this zone is one fairly persistent stringer of quartz and ore, which in part at least is a filled fissure. Most of the ore, however, occurs irregularly, replacing the quartzite near this principal fissure. The slaty beds contain many stringers of quartz and a little ore, but the quartzitic beds have been much more favorable to the processes of replacement whereby the greater part of the ore has been formed.

In its mineralogical character the ore is much like that of the Granite mine and is intimately associated with the same metamorphic silicates, particularly with garnet. Most of the specimens show pyrrhotite as well as galena, sphalerite, pyrite, and chalcopyrite. Siderite, so common in the Wardner and Mullan mines, is apparently absent in the Sixteen-to-One ore as it is in the Granite ore.

## CALIFORNIA CONSOLIDATED MINE.

The California Consolidated or Tamarack and Chesapeake mine is situated on the northeast side of Blackcloud Creek, three-fourths of a mile above its junction with Ninemile Creek. The lode was located in 1884 and has produced about $200,000 all told; but no deep continuation of the ore bodies had been found at the time of visit and lessees were merely cleaning up the ore left between the old stopes and the surface. Recent reports, however, indicate that valuable ore bodies have been found in the lower workings.

The underground workings consist of four main tunnels, with some minor openings. The lowest tunnel enters the hillside near the level of the creek. The others are at irregular vertical intervals and the total vertical range of exploration is probably 500 or 600 feet.

Throughout the workings the country rock is a fine-grained, rather thin-bedded white quartzite which shows much disturbance and in many places is shattered. As shown in Pl. II (in pocket), the geological structure in the vicinity of the mine is complicated by several faults whose combined effect has been to thrust up a mass of the Revett quartzite into the overlying St. Regis formation. It is in this relatively upthrust mass that the ore apparently occurs. The structure, however, is very obscurely shown on the surface and the underground workings throw little additional light upon it.

The ore occurs in a lode which strikes N. 75° W. and dips to the north at an angle estimated at 75°. It consists chiefly of earthy carbonate with some residual galena, the latter in some places running out into the country rock in little stringers. There are no well-defined walls and the ore was evidently deposited largely by replacement.

Just below No. 2 tunnel the ore abruptly ends. This point could not be seen at the time of visit, but is said to have been cut off by a "bed of talc"—that is, a fault gouge. As seen below the point where it cut off the ore this fault has a strike about parallel with the vein but dips at a lower angle, probably about 60°, to the north. The fissure contains a seam of very tough clay and is accompanied by much crushing of the adjacent quartzite. It has the general appearance of being younger than the vein, but as the actual intersection of the two was not visible this relation remains doubtful. A fissure carrying a little pyrite with specks of galena in a quartz gangue has been found in the foot wall of the fault, but it is doubtful whether it is the California vein. The structure near the mine is evidently complicated and is rendered obscure by the lack of local distinctive differences in the rocks of the various formations. Only the most detailed study, aided by accurate maps and sections and by systematic underground exploration, would be successful in unraveling the structure.

Under its new name, Tamarack and Chesapeake, the mine is credited with a production of 323 tons of ore in 1906, with a gross value of $19,589.

## SISTERS MINE.

The Sisters prospect is on the northwest side of Canyon Creek, about a mile and a half from Wallace. The developments consist of an adit level with drifts and crosscuts aggregating about 800 feet in length. The tunnel first follows the Osburn fault, here a great zone of breccia and gouge of unknown width, containing fragments of Prichard, Wallace, and other rocks. A northeast crosscut of about 225 feet goes through a much decomposed and fractured basic dike into a mass of crumpled, slickensided Prichard slate. The lode is in these disturbed slates and consists of a zone of soft, irregularly fissured rock containing stringers and bunches of ore. This consists of galena, with much sphalerite and pyrite, which occurs partly as distinct stringers with quartz gangue and partly as a replacement of the crushed slate. The ore itself shows evidence of movement since its deposition. No shipments had been made at the time of visit.

# CHAPTER XI.—OTHER MINES AND PROSPECTS.

## MINES BETWEEN WALLACE AND WARDNER.

### INTRODUCTION.

None of the mines between Wallace and Wardner has been continuously and profitably worked and all were idle in 1904. The ores occur in the green slaty rocks of the Wallace formation and are notable for their bunchy distribution and their relatively high tenor in silver. The failure to find large bodies of galena in these workings has led to the local designation of the strip of country in which they lie as "the dry belt."

### YANKEE BOY MINE.

The Yankee Boy mine is situated on the west side of the ridge between Big Creek and the head of Polaris Gulch, about 4 miles east-southeast of Wardner. The country rock is the typical green sericitic slate of the Wallace formation, the cleavage here striking nearly east and west, with a dip to the south of about 75°. The developments comprise two tunnels about 250 feet apart vertically and not connected. There are about 1,000 feet of workings in the lower tunnel, the upper one being less extensive.

The vein consists of stringers of quartz and follows the cleavage in general, although many of the individual stringers, which are very irregular, cut across the slates. The width of the vein is variable. In some places it consists of a single stringer 4 or 5 inches wide. In other places it is a stringer lode 2 or 3 feet wide.

The ore consists of galena, tetrahedrite, and proustite in an abundant gangue of quartz with some siderite. It is said to carry, when sorted for shipment, from 150 to 160 ounces of silver and from 30 to 40 per cent of lead. The mine has produced about $30,000, but has been idle since 1899. The ore shipped came from a stope about 100 feet in length above the upper tunnel. The pay shoot undoubtedly contains some rich ore, but it is narrow and has not been certainly identified in the lower tunnel, where three fissures have been cut.

### POLARIS MINE.

The Polaris was one of the first mines operated on the south side of the district, having been located in 1884 by W. B. Heyburn and others. It is situated near the head of Polaris Gulch, about 2½ miles west of Osburn.

The country rock is the green slate typical of the lower Wallace formation. The lode strikes about N. 60° E. and dips to the southeast at angles ranging from 50° to 80°. It cuts the bedding of the slates which strike about N. 70° W. and dip 60° SW. The developments consist of a tunnel on the vein about 800 feet long with a raise to the surface and a winze 120 feet deep. A short crosscut to the north, toward the Southern Cross vein, shows a few very narrow veins of siderite.

There are two shoots of ore in the Polaris. The first, near the portal of the tunnel, is about 50 feet in stope length and a foot in width. The second, about 600 feet from the portal is 150 feet in stope length and has a maximum width of 6 feet. The average width is about 2 feet. Both pay shoots are said to pitch to the east.

The ore consists of tetrahedrite, pyrite, and galena in a gangue of coarsely crystalline siderite and quartz. It appears to be in the main a fissure filling. The shipping ore is said to contain about 180 ounces of silver to the ton, with 10 per cent of copper and 8 per cent of lead. Some of the ore shipped in 1886 is said to have contained ruby silver (proustite). This is highly probable, although none of this mineral was noted by Mr. Calkins, who visited the mine in 1905 and obtained most of the data for this description. Proustite is known in the Yankee Boy, the next mine to the west. As in most of the mines of the so-called "dry belt," the ore, although very rich in silver, has not been found in shoots of such size as to lead to continuous and profitable mining.

### ARGENTINE MINE.

The Argentine mine, one of the older properties in the district, is in Argentine Gulch, about 2 miles west of Wallace. It is said to have shipped over 500 tons of ore carrying up to 20 ounces of silver to the ton. The mine has been idle for some years and the tunnels have caved. The dump indicates that the ore occurs in a large vein of coarsely crystalline siderite and quartz. Some copper was present with the lead and silver in the ore. The country rock is the Wallace formation.

### ALHAMBRA MINE.

The Alhambra prospect, part of the Bunker Hill and Sullivan property, is situated near the head of West Fork of Elk Creek, about a mile and a half southeast of Wardner. It is opened by a tunnel over 2,500 feet in length and some short drifts. No work was in progress at the time of visit and the full length of the tunnel could not be ascertained owing to the foulness of the air. The first drifts are on a fault between the Wallace formation on the north and the Revett quartzite. This is the Alhambra fault described by Mr. Calkins on page 63. The rocks on both sides of the fissure show slaty cleavage generally parallel to the fault, which dips southward at an angle of 50°.

The drifts farthest from the portal of the tunnel are on a fissure in quartzite which carries a little pyrite and chalcopyrite.

## PROSPECTS ON PINE CREEK.

### GENERAL SITUATION.

The Pine Creek prospects lie from 3 to 5 miles southwest of Wardner and for the most part outside of the area shown on Pl. I (in pocket). The only one examined in 1904 was the Highland Chief. This part of the district has recently shown increased activity, owing to the attention paid to zinc ores, and development has been in progress on several properties. Among these may be mentioned the Nabob, Surprise, and Douglas claims or groups.

### HIGHLAND CHIEF MINE.

The Highland Chief prospect is on East Fork of Pine Creek, about 1½ miles southwest of Kellogg Peak and just within the area mapped. The lode is in Prichard slate and apparently runs nearly northwest and southeast.

The principal opening is a crosscut tunnel just above the creek; this runs southward for about 340 feet to the lode. There is an irregular bunch of ore where the tunnel cuts the lode, but not enough work has been done to determine the size and shape of the body. The ore shows galena, zinc blende, pyrrhotite, chalcopyrite, and pyrite, with a gangue of quartz and unreplaced slate. None has been shipped and its tenor is not known.

The tunnel continues about 430 feet beyond the lode and crosses the Placer Creek fault (see p. 63) near the face. The quartzite south of the fault belongs to the Burke formation. It is greatly crushed and a strong stream of water issues from the fault breccia. The plane of dislocation is not well exposed but appears to be nearly vertical.

Another tunnel about 200 feet higher up the slope shows what is apparently the same zone of bunchy ore cut in the tunnel below. The ore for the most part has filled open spaces in a fissure zone in the slate, although there has been some replacement of the rock.

## MINES AND PROSPECTS ON PRICHARD CREEK.

### GENERAL STATEMENT.

Considerable desultory work has been done during the last fifteen years on a number of lead-silver deposits in the area of Prichard slate east of Murray. No commercial success had attended this effort up to the year 1904. Recently, however, the high price of lead has stimulated prospecting in this part of the district and at the date of writing (1907) some of the mines give promise of being profitably productive. Most of them are in the upper part of the Prichard formation, where sandy beds permit some replacement of galena similar to that which has taken place in the more quartzose Burke and Revett formations. The Prichard formation, however, can not be regarded as favorable to such extensive metasomatism as occurs in the Wardner, Canyon Creek, and Mullan groups of deposits.

### PARAGON MINE.

Work on the Paragon, which is situated in Paragon Gulch, east of Murray, began about 1890, but little was done until recently, when more extensive prospecting was commenced by the sinking of a 300-foot shaft. The lode, which runs about N. 70° W. and dips about 45° S., is in the Prichard formation, not far from the overlying Burke. The beds strike nearly north and south and have a dip of about 75° W. This dip, however, must be very local as the general dip of the formation in this vicinity is to the east, under the Burke.

The vein is a narrow zone of fissuring along which galena occurs in bunches where the fissure cuts the sandstone bands in the slates. The gangue is quartz and siderite and the ore bunches are for the most part metasomatic replacements.

All of the ore found up to the end of 1904 was near the surface and a few tons have been sacked for shipment. The new shaft is not on the vein and no crosscuts had been driven to the ore at the time of visit.

### BARTON OR MONARCH MINE.

Work on the Barton property seems to have begun about the same time as on the Paragon. Galena was encountered in 1890 and the discovery occasioned much local excitement over the prospect of a lead mine in the slates near Murray. Some ore was shipped near the end of 1898 and in 1899 the prospect was sold for $20,000. After several years of litigation and idleness the property passed into fresh hands and work was resumed in 1904.

The principal workings comprise a tunnel near the head of Barton Gulch and a long crosscut tunnel from Prichard Creek, a mile east of Raven. No ore has yet been found in the lower tunnel, which is probably over 1,000 feet below the upper workings.

As seen in the upper workings, the Barton is a well-defined vein in the Prichard formation. It contains in places galena and quartz to a width of 3 feet, with some replacement of the quartzitic beds in the slates. The vein strikes N. 35° W. and is about vertical.

Several tons of galena were ready for shipment at the time of visit and preparations were being made to sink a shaft on the ore.

### BEAR TOP MINE.

The Bear Top mine is about 5 miles east of Murray, on the north side of the ridge that separates the head of Paragon Gulch from Bear Gulch. The principal workings at the time of visit comprised a tunnel of 450 feet to the lode and drifts on the lode aggregating between 200 and 300 feet in length.

The lode is a rather irregular zone of fissuring which cuts the alternating quartzitic and slaty beds of the upper Prichard at a large angle, the strike of the lode being about N. 70° or 80° W. and the general strike of the beds being north. The beds dip eastward at angles ranging from 70° to 80°. The lode apparently dips to the south. As a rule these beds are sharply flexed and even brecciated close to the fissure zone. This zone is not continuous, but is offset by nearly north-south fissures which in some places probably correspond to the bedding planes. Some of the movement along these cross fissures is apparently later than the ore deposition, but some may have been earlier. So far as the small extent of the present workings allows generalization, the lode is apparently offset to the right as one goes east, a displacement that would correspond to reverse faulting. In consequence of this structure the ore occurs in bunches, the largest body exposed in 1904 being that where the tunnel cuts the lode. This is roughly triangular in plan, with sides about 30, 40, and 50 feet in length. (See fig. 23.) On the east this body is apparently cut off by a bedding fault or perhaps by the surface of a bed

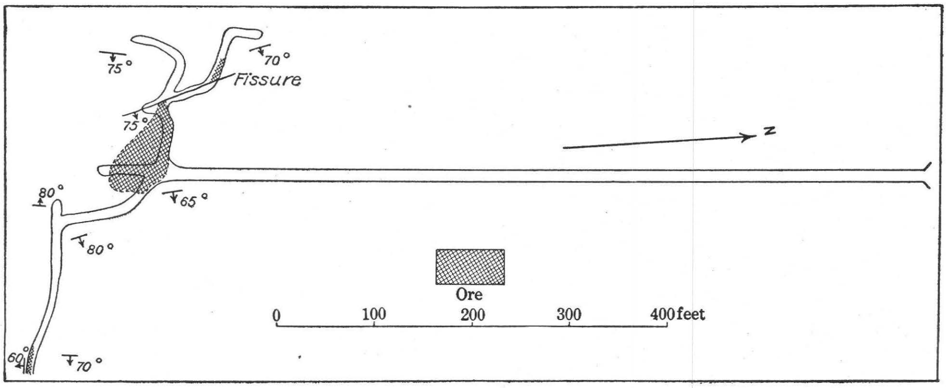



FIG. 23.—Sketch plan of the Bear Top mine.

not favorable to mineralization, and is succeeded by a barren interval of over 100 feet. Beyond this interval a 10-inch vein of nearly solid galena was exposed at the end of the east drift at the time of visit.

The ore occurs partly as the filling of fissures, but largely also as a replacement of the quartzite beds which are abundant in this part of the Prichard. It consists of galena, associated with sphalerite, pyrite, chalcopyrite, and calcite. No siderite was noted. As sorted for shipment it is said to carry up to 72 per cent of lead and 4 to 18 ounces of silver to the ton. A carload shipped in 1904 carried 6 ounces of silver and 72 per cent of lead. As in most of the lead-silver prospects in the Prichard formation, the galena is relatively low in silver.

The mine was equipped in 1904 with a sawmill and compressor, run by water. A concentrating mill of 50 tons capacity, also to be run by water power, was in process of construction. The Bear Top was productive in 1906.

# SURVEY PUBLICATIONS ON LEAD AND ZINC, GOLD AND SILVER, COPPER, AND TUNGSTEN DEPOSITS.

## LEAD AND ZINC.

Adams, G. I. Zinc and lead deposits of northern Arkansas. In Bulletin No. 213, pp. 187–196. 1903.

——— *See also* Bain, H. F., Van Hise, C. R., and Adams, G. I.

Bain, H. F. Lead and zinc deposits of Illinois. In Bulletin No. 225, pp. 202–207. 1904.

——— Zinc and lead deposits of the upper Mississippi Valley. Bulletin No. 294. 155 pp. 1906.

Bain, H. F., Van Hise, C. R., and Adams, G. I. Preliminary report on the lead and zinc deposits of the Ozark region (Mo., Ark.). In Twenty-second Ann. Rept., pt. 2, pp. 23–228. 1902.

Clerc, F. L. The mining and metallurgy of lead and zinc in the United States. In Mineral Resources U. S. for 1882, pp. 358–386. 1883.

Keith, A. Recent zinc mining in East Tennessee. In Bulletin No. 225, pp. 208–213. 1904.

Siebenthal, C. E. Mineral resources of northeastern Oklahoma. In Bulletin No. 340. 1908.

Smith, W. S. T. Lead and zinc deposits of the Joplin district, Missouri–Kansas. In Bulletin No. 213, pp. 197–204. 1903.

——— *See also* Ulrich, E. O., and Smith, W. S. T.

Ulrich, E. O., and Smith, W. S. T. Lead, zinc, and fluorspar deposits of western Kentucky. In Bulletin No. 213, pp. 205–213. 1903. Professional Paper No. 36. 1905.

Van Hise, C. R. *See* Bain, H. F., Van Hise, C. R., and Adams, G. I.

Winslow, A. The disseminated lead ores of southeastern Missouri. Bulletin No. 132. 31 pp. 1896.

Wolff, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin No. 213, pp. 214–217. 1903.

## GOLD AND SILVER.

Arnold, Ralph. Gold placers of the coast of Washington. In Bulletin No. 260, pp. 154–157. 1905.

Bain, H. F. Reported gold deposits of the Wichita Mountains (Okla.). In Bulletin No. 225, pp. 120–122. 1904.

Ball, S. H. Geological reconnaissance in southwestern Nevada and eastern California. In Bulletin 285, pp. 53–73. 1906. Also Bulletin No. 308. 218 pp. 1907.

Barrell, Joseph. Geology of the Marysville mining district, Montana. Professional Paper No. 57. 178 pp. 1907.

——— *See also* Weed, W. H., and Barrell, J.

Becker, G. F. Geology of the Comstock lode and the Washoe district; with atlas. Monograph III. 422 pp. 1882.

——— Gold fields of the southern Appalachians. In Sixteenth Ann. Rept., pt. 3, pp. 251–331. 1895.

——— Witwatersrand banket, with notes on other gold-bearing pudding stones. In Eighteenth Ann. Rept., pt. 5, pp. 153–184. 1897.

——— Brief memorandum on the geology of the Philippine Islands. In Twentieth Ann. Rept., pt. 2, pp. 3–7. 1900.

Boutwell, J. M. Progress report on Park City mining district, Utah. In Bulletins No. 213, pp. 31–40; No. 225, pp. 141–150; No. 260, pp. 150–153.

Collier, A. J. Gold-bearing river sands of northeastern Washington. In Bulletin No. 315, pp. 56–70. 1907.

Cross, Whitman. General geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp. 13–109. 1895.

——— Geology of Silver Cliff and the Rosita Hills, Colorado. In Seventeenth Ann. Rept., pt. 2, pp. 269–403. 1896.

Cross, Whitman, and Spencer, A. C. Geology of the Rico Mountains, Colorado. In Twenty-first Ann. Rept., pt. 2, pp. 15–165. 1900.

Curtis, J. S. Silver-lead deposits of Eureka, Nev. Monograph VII. 200 pp. 1884.

Diller, J. S. The Bohemia mining region of western Oregon, with notes on the Blue River mining region. In Twentieth Ann. Rept., pt. 3, pp. 7–36. 1900.

——— Mineral resources of the Indian Valley region, California. In Bulletin No. 260, pp. 45–49. 1905.

Diller, J. S., and Kay, G. F. The mines of the Riddles quadrangle, Oregon. In Bulletin No. 340. 1908.

Eckel, E. C. Gold and pyrite deposits of the Dahlonega district, Georgia. In Bulletin No. 213, pp. 57–63. 1903.

Eldridge, G. H. Reconnaissance in the Sushitna basin and adjacent territory in Alaska in 1898. In Twentieth Ann. Rept., pt. 7, pp. 1–29. 1900.

EMMONS, S. F. Geology and mining industry of Leadville, Colo.; with atlas. Monograph XII. 870 pp. 1886.
——— Progress of the precious-metal industry in the United States since 1880. In Mineral Resources U. S. for 1891, pp. 46–94. 1892.
——— Economic geology of the Mercur mining district, Utah. In Sixteenth Ann. Rept., pt. 2, pp. 349–369. 1895.
——— The mines of Custer County, Colo. In Seventeenth Ann. Rept., pt. 2, pp. 411–472. 1896.
EMMONS, W. H. The Neglected mine and near-by properties, Colorado. In Bulletin No. 260, pp. 121–127. 1905.
——— Ore deposits of Bear Creek, near Silverton. In Bulletin No. 285, pp. 25–27. 1906.
——— Notes on the Manhattan district (Nevada). With Ransome and Garrey in Bulletin No. 303.
——— The Granite-Bimetallic and Cable mines, Philipsburg quadrangle, Mont. In Bulletin No. 315, pp. 31–55. 1907.
——— Gold deposits of the Little Rocky Mountains, Montana. In Bulletin No. 340. 1908.
GALE, H. S. Hahns Peak gold field. In Bulletin No. 285, pp. 28–34. 1906.
——— Gold placer deposits near Lay, Routt County, Colo. In Bulletin No. 340. 1908.
GARREY, G. H. Notes on the Manhattan district (Nevada). With Ransome and Emmons in Bulletin No. 303.
——— *See also* Spurr, J. E., and Garrey, G. H.
GRATON, L. C. Gold and tin deposits of the southern Appalachians; with notes on the Dahlonega mines by Waldemar Lindgren. Bulletin No. 293. 134 pp. 1906.
——— *See also* Lindgren, W., and Graton, L. C.
HAGUE, ARNOLD. Geology of the Eureka district, Nevada. Monograph XX. 419 pp. 1892.
HAHN, O. H. The smelting of argentiferous lead ores in the Far West. In Mineral Resources for 1882, pp. 324–345. 1883.
IRVING, J. D. Ore deposits of the northern Black Hills. In Bulletin No. 225, pp. 123–140. 1904.
——— Ore deposits of the Ouray district, Colorado. In Bulletin No. 260, pp. 50–77. 1905.
——— Ore deposits in the vicinity of Lake City, Colo. In Bulletin No. 260, pp. 78–84. 1905.
KAY, G. F. *See* Diller, J. S., and Kay, G. F.
LINDGREN, WALDEMAR. The gold-silver mines of Ophir, Cal. In Fourteenth Ann. Rept., pt. 2, pp. 243–284. 1894.
——— The gold-quartz veins of Nevada City and Grass Valley districts, California. In Seventeenth Ann. Rept., pt. 2, pp. 1–262. 1896.
——— The mining districts of the Idaho basin and the Boise Ridge, Idaho. In Eighteenth Ann. Rept., pt. 3, pp. 625–736. 1898.
——— The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho. In Twentieth Ann. Rept., pt. 3, pp. 75–256. 1900.
——— The gold belt of the Blue Mountains of Oregon. In Twenty-second Ann. Rept., pt. 2, pp. 551–776. 1902.
——— Neocene rivers of the Sierra Nevada. In Bulletin No. 213, pp. 64–65. 1903.
——— Mineral deposits of the Bitterroot Range and the Clearwater Mountains, Montana. In Bulletin No. 213, pp. 66–70. 1903.
——— Tests for gold and silver in shales from western Kansas. Bulletin No. 202. 21 pp. 1902.
——— The production of gold in the United States in 1904. In Bulletin No. 260, pp. 32–38. 1905.
——— The production of silver in the United States in 1904. In Bulletin No. 260, pp. 39–44. 1905.
——— The Annie Laurie mine, Piute County, Utah. In Bulletin No. 285, pp. 87–90. 1906.
——— Notes on the Dahlonega mines. In Bulletin No. 293, pp. 119–128. 1906.
——— A geological analysis of the silver production of the United States. In Bulletin No. 340. 1908.
——— *See also* Graton, L. C.
LINDGREN, WALDEMAR, and GRATON, L. C. Mineral deposits of New Mexico. In Bulletin No. 285, pp. 74–86. 1906.
LINDGREN, WALDEMAR, and RANSOME, F. L. The geological resurvey of the Cripple Creek district. Bulletin No. 254. 36 pp. 1905.
——— ——— Geology and gold deposits of the Cripple Creek district, Colorado. Professional Paper No. 54. 516 pp. 1906.
LORD, E. Comstock mining and miners. Monograph IV. 451 pp. 1883.
McCASKEY, H. D. Some gold deposits of Alabama. In Bulletin No. 340. 1908.
MACDONALD, D. F. Economic features of northern Idaho and northeastern Montana. In Bulletin No. 285, pp. 41–52. 1906.
NITZE, H. B. C. History of gold mining and metallurgy in the Southern States. In Twentieth Ann. Rept., pt. 6, pp. 111–123. 1899.
PENROSE, R. A. F., jr. Mining geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp. 111–209. 1895.
PIRSSON, L. V. *See* Weed, W. H., and Pirsson, L. V.
PURINGTON, C. W. Preliminary report on the mining industries of the Telluride quadrangle, Colorado. In Eighteenth Ann. Rept., pt. 3, pp. 745–850. 1898.
RANSOME, F. L. Report on the economic geology of the Silverton quadrangle, Colorado. Bulletin No. 182. 265 pp. 1901.
——— The ore deposits of the Rico Mountains, Colorado. In Twenty-second Ann. Rept., pt. 2, pp. 229–398. 1902.
——— Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada; with notes on the Manhattan district by G. H. Garrey and W. H. Emmons. Bulletin No. 303. 98 pp. 1907.

Ransome, F. L. *See also* Lindgren, W., and Ransome, F. L.
Schrader, F. C. The mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz. In Bulletin No. 340. 1908.
Schultz, A. R. Gold development in central Uinta County, Wyo., and at other points on Snake River. In Bulletin No. 315, pp. 71–88. 1907.
Smith, G. O. Gold mining in central Washington. In Bulletin No. 213, pp. 76–80. 1903.
——— Quartz veins in Maine and Vermont. In Bulletin No. 225, pp. 81–88. 1904.
——— *See also* Tower, G. W., and Smith, G. O.
Spencer, A. C. *See* Cross, Whitman, and Spencer, A. C.
Spurr, J. E. Economic geology of the Mercur mining district, Utah. In Sixteenth Ann. Rept., pt. 2, pp. 343–455. 1895.
——— Geology of the Aspen mining district, Colorado; with atlas. Monograph XXX. 260 pp. 1898.
——— The ore deposits of Monte Cristo, Washington. In Twenty-second Ann. Rept., pt. 2, pp. 777–866. 1902.
——— Ore deposits of Tonopah and neighboring districts, Nevada. In Bulletin No. 213, pp. 81–87. 1903.
——— Preliminary report on the ore deposits of Tonopah. In Bulletin No. 225, pp. 89–110. 1904.
——— Ore deposits of the Silver Peak quadrangle, Nevada. In Bulletin No. 225, pp. 111–117. 1904.
——— Notes on the geology of the Goldfield district, Nevada. In Bulletin No. 225, pp. 118–129. 1904.
——— Geology of the Tonopah mining district, Nevada. Professional Paper No. 42. 295 pp. 1905.
——— The ores of Goldfield, Nev. In Bulletin No. 260, pp. 132–139. 1905.
——— Developments at Tonopah during 1904. In Bulletin No. 260, pp. 140–149. 1905.
——— Ore deposits of the Silver Peak quadrangle, Nevada. Professional Paper No. 55. 174 pp. 1906.
Spurr, J. E., and Garrey, G. H. Preliminary report on the ore deposits of the Georgetown mining district, Colorado. In Bulletin No. 260, pp. 99–120. 1905.
——— ——— The Idaho Springs mining district, Colorado. In Bulletin No. 285, pp. 35–40. 1906.
Tower, G. W., and Smith, G. O. Geology and mining industry of the Tintic district, Utah. In Nineteenth Ann. Rept., pt. 3, pp. 601–767. 1899.
Weed, W. H. Geology of the Little Belt Mountains, Montana, with notes on the mineral deposits of the Neihart, Barker, Yogo, and other districts. In Twentieth Ann. Rept., pt. 3, pp. 271–461. 1900.
——— Gold mines of the Marysville district, Montana. In Bulletin No. 213, pp. 88–89. 1903.
——— Notes on the gold veins near Great Falls, Md. In Bulletin No. 260, pp. 128–131. 1905.
Weed, W. H., and Barrell, J. Geology and ore deposits of the Elkhorn mining district, Jefferson County, Mont. In Twenty-second Ann. Rept., pt. 2, pp. 399–550. 1902.
Weed, W. H., and Pirsson, L. V. Geology of the Castle Mountain mining district, Montana. Bulletin No. 139. 164 pp. 1896.
——— ——— Geology and mining resources of the Judith Mountains of Montana. In Eighteenth Ann. Rept., pt. 2, pp. 446–616. 1898.
Weeks, F. B. Geology and mineral resources of the Osceola mining district, White Pine County, Nev. In Bulletin No. 340. 1908.
Williams, A. Popular fallacies regarding precious-metal ore deposits. In Fourth Ann. Rept., pp. 253–271. 1884.
Woolsey, L. H. Lake Fork extension of the Silverton mining area, Colorado. In Bulletin No. 315, pp. 26–30. 1907.

## COPPER.

Bain, H. F., and Ulrich, E. O. The copper deposits of Missouri. In Bulletin No. 260, pp. 233–235. 1905.
Ball, S. H. Copper deposits of the Hartville uplift, Wyoming. In Bulletin No. 315, pp. 93–107. 1907.
Boutwell, J. M. Ore deposits of Bingham, Utah. In Bulletin No. 213, pp. 105–122. 1903.
——— Economic geology of the Bingham mining district, Utah. Professional Paper No. 38. 413 pp. 1905.
——— Ore deposits of Bingham, Utah. In Bulletin No. 260, pp. 236–241. 1905.
Collier, A. J. Ore deposits of the St. Joe River basin, Idaho. In Bulletin No. 285, pp. 129–139. 1906.
Diller, J. S. Copper deposits of the Redding region, California. In Bulletin No. 213, pp. 123–132. 1903.
——— Mining and mineral resources in the Redding district in 1903. In Bulletin No. 225, pp. 169–179. 1904.
Emmons, S. F. Economic geology of the Butte (copper) district, Montana. Geologic Atlas U. S., folio No. 38. 1897.
——— Copper in the Red Beds of the Colorado plateau region. In Bulletin No. 260, pp. 221–232. 1905.
——— The Cactus copper mine, Utah. In Bulletin No. 260, pp. 242–248. 1905.
Emmons, W. H. The Cashin mine, Montrose County, Colo. In Bulletin No. 285, pp. 125–128. 1906.
Heikes, V. C. *See* Weeks, F. B., and Heikes, V. C.
Irving, R. D. The copper-bearing rocks of Lake Superior. Monograph V. 464 pp. 1883.
Lindgren, W. The copper deposits of the "Seven Devils," Idaho. In Mining and Scientific Press, vol. 78, p. 125. 1899.
——— Copper deposits at Clifton, Ariz. In Bulletin No. 213, pp. 133–140. 1903.
——— Copper deposits of Clifton-Morenci district, Arizona. Professional Paper No. 43. 375 pp. 1905.
——— Notes on copper deposits in Chaffee, Fremont, and Jefferson counties, Colo. In Bulletin No. 340. 1908.
Phalen, W. C. Copper deposits near Luray, Va. In Bulletin No. 285, pp. 140–143. 1906.
Pirsson, L. V. *See* Weed, W. H., and Pirsson, L. V.

Ransome, F. L. Copper deposits of Bisbee, Ariz. In Bulletin No. 213, pp. 149–157. 1903.
——— The Globe copper district, Arizona. Professional Paper No. 12. 168 pp. 1904.
——— Geology and ore deposits of the Bisbee quadrangle, Arizona. Professional Paper No. 21. 168 pp. 1904.
Spencer, A. C. Mineral resources of the Encampment copper region, Wyoming. In Bulletin No. 213, pp. 158–162. 1903.
——— Reconnaissance examination of the copper deposits at Pearl, Colo. In Bulletin No. 213, pp. 163–169. 1903.
——— Copper deposits of the Encampment district, Wyoming. Professional Paper No. 25. 107 pp. 1904.
Ulrich, E. O. *See* Bain, H. F., and Ulrich, E. O.
Watson, T. L. Notes on the Seminole copper deposits of Georgia. In Bulletin No. 225, pp. 182–186.
Weed, W. H. Ore deposits at Butte, Mont. In Bulletin No. 213, pp. 170–180. 1903.
——— Copper deposits of the Appalachian States. In Bulletin No. 213, pp. 181–185. 1903.
——— Copper deposits in Georgia. In Bulletin No. 225, pp. 180–181. 1904.
——— The Griggstown, N. J., copper deposit. In Bulletin No. 225, pp. 187–189. 1904.
——— Notes on the copper mines of Vermont. In Bulletin No. 225, pp. 190–199. 1904.
——— The copper deposits of eastern United States. In Bulletin No. 260, pp. 217–220. 1905.
——— The copper mines of the United States in 1905. In Bulletin No. 285, pp. 93–124. 1906.
Weed, W. H., and Pirsson, L. V. Geology of the Castle Mountain mining district, Montana. Bulletin No. 139. 164 pp. 1896.
Weeks, F. B., and Heikes, V. C. Notes on the Fort Hall mining district, Idaho. In Bulletin No. 340. 1908.

## TUNGSTEN.

Hess, F. L. Note on a tungsten-bearing vein near Raymond, Cal. In Bulletin No. 340. 1908.
Hobbs, W. H. The old tungsten mine at Trumbull, Conn. In Twenty-second Ann. Rept., pt. 2, pp. 7–22. 1902.
——— Tungsten mining at Trumbull, Conn. In Bulletin No. 213, p. 98. 1903.
Weeks, F. B. An occurrence of tungsten ore in eastern Nevada. In Twenty-first Ann. Rept., pt. 6, pp. 319–320. 1901.
——— Tungsten ore in eastern Nevada. In Bulletin No. 213, p. 103. 1903.
——— Tungsten deposits in the Snake Range, White Pine County, eastern Nevada. In Bulletin No. 340. 1908.

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